Managing technological open process innovation

An empirical lifecycle perspective on the management of external contributions to process development and implementation in large manufacturing companies

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Abstract

It is well documented that large manufacturing companies often draw on external knowledge and technology for process innovation. Yet, the management of knowledge and technology transfer at different stages of the innovation lifecycle has received very little scholarly attention. Previous studies in this domain only focus on buyer-supplier interaction for technology development. As a result, theory on open process innovation remains significantly underdeveloped regarding external contributions to aspects of process innovation other than technological change and by different types of external partners. This also entails a lack of discussion on openness (search breadth and depth) and the deployment of absorptive capabilities at the lifecycle stage level. The present thesis addresses these gaps through an exploratory, multiple case-study of five large manufacturing companies operating in different industries in Germany. The study develops a conceptual framework to identify key categories of inquiry and uses cross-case analysis to enable the development of four theoretical constructs that capture central mechanisms of open process innovation. Specifically, the study identifies different forms of external contributions to technological change involving different configurations of openness. The findings suggest that the motivation for interaction, the relevance of knowledge protection, and the availability of external information at any given stage determine a company's openness and therefore which contribution it obtains at that stage. In this context the study identifies different patterns for the development of enabling and core processes. Furthermore, the thesis uncovers mechanisms of indirect external contributions to organizational change and systemic impact management, which are particularly relevant when external partners lack sufficient organizational insight or internal acceptance to provide direct contributions. By investigating a broader range of external partners than previous studies the thesis also emphasizes the importance of methodological guidance by management consultants during early stages of projects with a broad scope. Linking the findings to the literature on absorptive capacity the thesis argues that it is a central managerial task to dynamically adjust the practices underlying absorptive capabilities from conceptual process planning to practical adaptation and integration efforts in order to obtain external contributions to process development and implementation. By accounting for various determinants of process innovation and open innovation, as well as the deployment of absorptive capabilities at different lifecycle stages the constructs presented in this thesis enable a more granular perspective on open process innovation than previous literature has offered and lead to several recommendations for managerial practice.

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Author's declaration

I hereby declare that this thesis entitled "Managing technological open process innovation: an empirical lifecycle perspective on the management of external contributions to process development and implementation in large manufacturing companies" represents my own work and that any references to work by others have been clearly specified and acknowledged throughout the thesis.

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1   Introduction

This thesis investigates technological open process innovation from a lifecycle perspective. The following chapter introduces the research problem and points out knowledge gaps in the existing literature. Afterwards, the chapter outlines the objectives and the scope of this thesis. The chapter then provides an overview of the methods that were applied to investigate open process innovation the research design and a summary of the study's key findings and contributions. Finally the chapter concludes with an outline of the thesis' structure.

1.1   Research problem and knowledge gap

Technological process innovation (hereafter process innovation) is an important source of competitive advantage (Dodgson et al., 2008; Schallock, 2010). It can increase production yield, lower production costs (Browning & Heath, 2009), improve product and service quality (Reichstein & Salter, 2006), operational flexibility (Upton, 1997), controllability (Zelbst et al., 2012), as well as environmental sustainability (Kleindorfer et al., 2005), and speed-up time-to-market (Hayes et al., 2005).

Despite its importance for competitive advantage, process innovation remains understudied (Keupp et al., 2012; Piening & Salge, 2015). Process innovation differs conceptually from other forms of innovation (Becheikh et al., 2006; Gopalakrishnan et al., 1999; Lu & Botha, 2006). It involves a distinctive set of components that make it a unique organizational phenomenon. Driven by internal requirements, processes are typically commercialized within the company, and are only indirectly triggered by market demand (Damanpour & Gopalakrishnan, 2001; Damanpour et al., 2009). Furthermore, process innovation is characterized by mutual adaptation of new technology and existing organization (Leonard-Barton, 1988; Majchrzak et al., 2000; Tyre & Orlikowski, 1994), technological and organizational change (Reichstein & Salter, 2006; Womack et al., 1990) and systemic impact (Gopalakrishnan et al., 1999). Companies, therefore have to cope with a variety of tasks and challenges to successfully generate process innovation.

Regardless of size, companies do not usually have the resources or the desire to develop all relevant technologies internally. Large manufacturing companies, for example, often acquire new process equipment from external sources (Reichstein & Salter, 2006). Against this backdrop, the innovation literature distinguishes between innovation that is developed within and across organizational boundaries (Dahlander & Gann, 2010; Gassmann & Enkel, 2004; West & Bogers, 2014). Open innovation has emerged as a collective paradigm for research on innovation processes across organizational boundaries (Chesbrough & Teece, 2002; Gassmann

et al., 2010; Huizingh, 2011; Lichtenthaler, 2011). A substantial body of literature on various aspects of collaborative innovation has emerged under the umbrella term of open innovation, since the publication of Henry Chesbrough's (2003) book of the same name (Gassmann et al., 2010; Lichtenthaler, 2011). Nevertheless, research predating open innovation remains equally important. Earlier concepts such as the exploration-exploitation framework (March, 1991), absorptive capacities (Cohen & Levinthal, 1990; Zahra & George, 2002), dynamic capabilities (Eisenhardt & Martin, 2000; Teece et al., 1997), or resource-based and relational views of the organization (Dyer & Singh, 1998) frequently inform research within the open innovation domain (Dahlander & Gann, 2010).

The existing open innovation literature focuses primarily on product innovation. Open process innovation remains relatively neglected (Huizingh, 2011; Robertson et al., 2012; West & Gallagher, 2006). The current state of research leaves decision makers uninformed on the systematic management of open process innovation (Huang & Rice, 2012; Terjesen & Patel, 2014). Yet, open process innovation is a difficult managerial challenge, which has to take the following issues into account. External actors hold important technological developments and knowledge. Absorbing new knowledge involves learning and interaction with external partners (Lager & Frishammar, 2010). At the same time, external actors lack insight into the organization's (tacit) knowledge base (Huizingh, 2011). Companies may, however, be reluctant to reveal internal knowledge in order to appropriate process innovation (James et al., 2013; Milesi et al., 2013). This begs the question whether open innovation is as powerful a framework for process innovation as it is for product innovation (West & Gallagher, 2006). Previous studies on open process innovation mainly focus on external contributions towards technological change (Frishammar et al., 2012). It is not clear whether, to what extent, and how external partners affect process innovation components other than technological change.

Openness towards external partners has been conceptualized in various ways (Dahlander & Gann, 2010; Huizingh, 2011; Lazzarotti et al., 2011). Most studies investigate openness on the aggregate company or project-level (Bahemia & Squire, 2010; Horváth & Enkel, 2014). Yet, managing openness on the operational level is still not well understood. Companies plan, develop, and install new processes along different project stages. However, different project stages provide different conditions and requirements for the interaction with external partners (Lager & Frishammar, 2012; Rönnberg-Sjödin, 2013). An innovation lifecycle perspective is therefore necessary for the study of openness on the operational level. Innovation lifecycle models suggest that innovation is a process that comprises both invention and commercialization (Crossan & Apaydin, 2010). The literature provides a variety of lifecycle models, such as the stage-gate-model (Cooper, 1990). As process innovation comprises specific components, these need to be clearly emphasized throughout the innovation lifecycle (Cooper,

2007; Kurkkio et al., 2011; Lager, 2011; Lu & Botha, 2006). Few studies have investigated open process innovation from a lifecycle perspective. Existing research focuses on the interaction between equipment buyers and suppliers (Lager & Frishammar, 2012; Rönnberg-Sjödin, 2013). The focus on external contributions to technological change while neglecting other components of process innovation is a critical limitation. The increasing pace and dispersed loci of relevant knowledge present companies with the challenge of searching for innovation from a variety of different types of external sources (Reichstein & Salter, 2006). Therefore, the existing knowledge on open process innovation from a lifecycle perspective is limited due to a lack of research on the effect of external contributions beyond technological change and by other external partners than technology suppliers.

The existing open process innovation literature is further limited in the extent to which it discusses the management of openness and its specific determinants. Literature on inter-organizational collaboration argues that knowledge and technology transfer involves close interaction between the source and the recipient (Lager & Frishammar, 2010; Trott et al., 1995). The integration of external partners for process innovation, however, poses a particular challenge in this context, as companies usually seek appropriation of process innovation through means of secrecy (James et al., 2013; Milesi et al., 2013). Furthermore, a company's internal process knowledge is often tacit in nature and thus difficult to convey to external partners (Gopalakrishnan et al., 1999; Gopalakrishnan & Bierly, 2001), especially when relationships are recent and trust has yet to be built. In this context companies have to manage openness in a way to recognize, assimilate, transform, and exploit new knowledge (Zahra & George, 2002). Previous research is lacking a discussion on the adjustment of openness in terms of search breadth and depth across the stages of the innovation lifecycle. Likewise, previous research has paid relatively little attention to understanding absorptive capabilities for process innovation (Piening & Salge, 2015) and open process innovation (Robertson et al., 2012) as well as to the routines by which companies deploy them (Comacchio & Bonesso, 2012; Lewin et al., 2011). Given this background, qualitative approaches to studying search breadth and depth provide the opportunity to understand how companies adjust openness and manage knowledge absorption as well as technology transfer throughout the innovation lifecycle.

In summary, theory on open process innovation from a lifecycle perspective is nascent. The existing literature does not sufficiently incorporate insights from the streams of literature on open innovation (multiple partners, breadth and depth dimensions of openness), process innovation (different components), and open process innovation (specific determinants, absorptive capacity). As a result there remains a knowledge gap regarding the understanding of open process innovation management from a lifecycle perspective with specific regard to the

components underlying process innovation, different external partners, and the deployment of absorptive capabilities.

1.2 Main objectives and research questions

The main objective of this study is to contribute to the emerging literature on open process innovation. In particular, the study aims to develop theoretical constructs that capture the mechanisms governing open process innovation throughout the innovation lifecycle. This includes the following sub-objectives.

- **Content of process innovation components:** The study seeks to identify the content of different process innovation components. A component is a constituent part of a larger whole. This means a component refers to a domain or an issue that is an integral part of a larger theoretical domain, under which it is subsumed in combination with other such theoretical domains to conjointly describe the phenomenon as a whole. Process innovation components refer to the theoretical constituents of the process innovation phenomenon (mutual adaptation of new technology and existing organization; technological change; organizational change; systemic impact) along the innovation lifecycle. Explicitly capturing the content of different components dissects process innovation into its building blocks. This provides a transparent and fertile ground for the investigation of open process innovation. Without such a distinction, research on external contributions to process innovation remains undifferentiated and limited. The major focus on technological change in the existing literature on open process innovation reflects this issue.

- **Motivation for interaction and content of openness:** The study seeks to identify patterns of motivation and openness to obtain external contributions to process innovation at different lifecycle stages. Motivation refers to the reasons for interaction. Openness refers to external search breadth and depth (Laursen & Salter, 2006). The present study draws on qualitative data to elicit the contents of motivation and openness. This also includes an investigation of the linkages between openness, motivation, and the different process innovation components.

- **Capability deployment:** Inbound open innovation presupposes that companies have capacities to absorb externally generated knowledge and technology to advance internal innovation efforts. The study seeks to uncover general classes of practices and routines by which companies deploy absorptive capabilities throughout the innovation lifecycle.

By advancing a routine-based approach, the study aims to provide insight into the black box of absorptive capacity (cf. Lewin et al., 2011).

In context of these objectives the study addresses the following research questions as listed in Table 1.

Table 1: Research questions

Key research questions	
Research question	How and why do large manufacturing companies collaborate with different external partners throughout the process innovation lifecycle?
Sub-question 1	How is process development and implementation characterized in terms of activities, outputs, and challenges relating to technological and organizational change, as well as to the management of mutual adaptation and systemic impact at different stages of the process innovation lifecycle?
Sub-question 2	What are the key motivations for companies to interact / not interact with external partners at each lifecycle stage?
Sub-question 3	What are the key determinants of openness in terms of search breadth and depth at each lifecycle stage?
Sub-question 4	How do companies deploy absorptive capabilities throughout the innovation lifecycle to facilitate knowledge absorption and inbound technology transfer?

1.3   Scope of the thesis

The present study was conducted within specific boundaries. The following points define the scope of the present thesis.

- **Relevant literature:** This thesis mainly draws on innovation management literature relating to research and development, technology management, and initial process application. This domain overlaps with those categories of operations management concerned with the design, development, and implementation of process technologies and work organization.

- **Innovation lifecycle:** The term "innovation lifecycle" denotes the sequence of activities relating to development and implementation. This study uses the term "innovation lifecycle" rather than "innovation process" to prevent confusion with "process innovation". In general, lifecycle perspectives cover the timespan from the beginning to the end of a specific phenomenon. The "innovation lifecycle" refers to the timespan of an innovation project, rather than its outcome. The innovation lifecycle therefore begins

with idea generation (ideation) and ends with implementation but does not include routine process operation.

- **Technological process innovation:** The present study focuses on technological process innovation (see definition in section 2.2). This refers to process innovation driven by the introduction of new hardware and software technology. This may demand organizational changes or be constrained by existing organizational structures. However, the research does not focus on process innovation that is initially driven by organizational change or that does not involve new technology at all. While these are all important and legitimate phenomena, covering all forms of process innovation is beyond the scope of this thesis.

- **Process type and project scope:** The study covers innovation in enabling processes as well as core processes. Core processes refer directly to those operations that describe a company's primary value creation performance. Enabling processes facilitate but do not directly relate to the company's primary operations. Furthermore, the study distinguishes between broad and narrow scope innovation projects. Broad scope projects include technological and organizational change. They involve a focus on one or more technologies. They involve organizational change across multiple organizational departments and functions and possibly multiple sites at the same time. Narrow scope projects include mainly technological change and require only minor organizational change coordination Involve only one technology. They are limited to a specific department or setting. Furthermore, they involve organizational change which are limited to a specific department or setting and do not include simultaneous roll-out in various heterogeneous functions, departments, or locations.

- **Large companies:** The study investigates open process innovation in the context of large manufacturing companies. Such companies often have strong technological competences and make substantial investments in process innovation and interaction with external partners. Yet, they are typically characterized by departmentalization and hierarchical structures that impede flexibility. In conjunction, this constitutes a challenging environment for managing open process innovation, and thus a fertile grounding for the research carried out in the present study.

1.4 Overview of research design

The study adopts an exploratory case-based research design, the aim of which is to develop constructs that describe open process innovation from a lifecycle perspective. This approach

was chosen with regard to the nascent state of current theory, the exploratory research objective, and the complex nature of the phenomenon under investigation. The study mainly follows the procedures for theory-building case research, as suggested by Eisenhardt (1989). Moreover, it applies several analytical tools outlined by Miles and Hubermann (1994). These approaches are reflected in the study's ambition to develop theoretical constructs from empirical data without imposing a priori hypotheses or committing to a specific theoretical perspective. Instead, the study draws on a variety of literature to devise an initial framework for data collection and analysis. The thesis focuses on the general phenomenon of open process innovation from a lifecycle perspective rather than company-specific instances thereof. Two units of analysis are therefore addressed: open process innovation at individual lifecycle stages, and at the aggregate lifecycle level. The study includes multiple cases that provide the context for the study. Multiple cases enable replication logic and cross-case analysis to dissociate general patterns from case-specific idiosyncrasies (Eisenhardt, 1989). Data were collected from BMW, Knorr-Bremse, Thyssen Krupp Marine Systems, ZF Friedrichshafen, and TE Connectivity. The dataset comprises about 91.5 hours of semi-structured interviews with 32 knowledgeable experts, as well as secondary data and field notes.

1.5 Key findings and contributions

The thesis contributes to the literature on innovation management, and open process innovation in particular, by advancing a lifecycle perspective on the management of open process innovation and developing theoretical constructs that capture key mechanisms of this phenomenon. The thesis provides one of the first empirical studies to explore open process innovation from a lifecycle perspective and explicitly accounts for multiple process innovation components, different external partners and development contingencies, as well as the deployment of absorptive capabilities during the interaction with external partners for process development and implementation. The main findings can be summarized as follows.

- **Different paths of open process innovation for technological change:** The findings of the study lead to a construct that shows how different patterns of openness emerge across the stages of the process innovation lifecycle and the determinants that affect them. The construct suggests that the motivation to interact with external technology partners changes throughout the innovation lifecycle. At the same time, companies adjust their openness to match the motivation for interaction but also to account for the relevance of knowledge protection and the availability of external information, which in turn depend on the type of process a company develops. To this background the study suggests that companies seek different contributions to technological change throughout

the innovation lifecycle. These contributions refer to capability and capacity contributions, whereas the thesis establishes a further distinction between conceptual and applied capability contributions. Different paths for seeking these contributions throughout the innovation lifecycle are documented for the development of enabling and core processes.

- **Limited and indirect contributions:** The findings suggest that direct external contributions are predominantly relevant for technological change. Lacking organizational insight and lacking internal acceptance ofexternal partners by internal operators are identified as major impediments for external contributions to organizational change. At the same time, by accounting for different process innovation components and their content at different lifecycle stages, the study develops a construct that captures the mechanism of indirect external contributions to mutual adaptation, organizational change and systemic impact. The study defines this construct and delimits it from previous notions of indirect knowledge transfer.

- **Different types of partners:** Concurring with previous research the results show that external contributions to technological change are relevant throughout the entire innovation lifecycle. However, the thesis contributes a broader perspective on open process innovation by investigating different types of external partners. In particular, the study provides empirical evidence to suggest that management consultants support process development mainly by providing methodological guidance during early lifecycle stages in projects with a broad scope.

- **Open process innovation capabilities:** Based on the results and analysis of observable routines and practices, the thesis advances a perspective on knowledge absorption as an interactive and gradual process in which companies deploy different capabilities simultaneously and across multiple lifecycle stages. Yet, the routines and practices by which companies enact these capabilities differ throughout the innovation lifecycle, changing from conceptually-focused to more applied efforts. By adopting a routine-based approach to the study of absorptive capacity the thesis contributes to the knowledge of the underlying practices that constitute absorptive capacity and shows how knowledge absorption actually occurs. Based on these insights the thesis concludes that the management of open process innovation constitutes a dynamic capability.

1.6 Outline of thesis structure

The thesis comprises different theoretical and empirical chapters that build on each other to investigate open process innovation from a lifecycle perspective. (see Figure 1).

- **Theory chapters:** Following this introduction, the literature review in chapter 2 discusses key concepts of innovation management research and important previous research to deeply ground the study in the academic discourse on open process innovation. The literature review comprises five main domains: innovation and process innovation; open innovation; innovation lifecycle perspectives including the process innovation lifecycle; open process innovation; and open process innovation from a lifecycle perspective. Building on the insights from the literature review, chapter 2.7 devises initial categories for the exploration of open process innovation from a lifecycle perspective and describes their measurement. The framework focuses in particular on process innovation components, motivation for interaction, openness, capability deployment, and the process innovation lifecycle.

- **Methodology chapter:** Following the theory chapters, chapter 4 introduces the methodological approach of this thesis. The chapter justifies the choice of a case-based research design and explains the procedures or case selection and data collection. In order to achieve transparency and credibility, a particular focus is put on the analytical procedures that lead from data to findings. The chapter concludes with an outline of the measures taken to ensure validity and reliability.

- **Analysis chapters:** The empirical part of the thesis begins with individual summaries of key insights from the five case study companies in chapter 5. This covers the companies' background, the type of process innovation and project scope they reported on, responsibilities of the task force, the role of external partners, and the relevance of knowledge protection. The cross-case results and their discussion are presented in chapters 6 and 7. First, each lifecycle stage is examined separately in chapter 6. This includes the descriptive results for process innovation components, motivation for interaction, and openness at each lifecycle stages, as well as an analytical discussion to elicit emergent themes at each stage. The general discussion in chapter 7 then synthesizes the themes from the individual stages and elaborates on the emergent open process innovation constructs from an aggregate perspective.

- **Concluding chapter:** Chapter 8 concludes the thesis with an outline of the theoretical contributions, managerial implications, and limitations, and offers a perspective for future research.

Chapter 1: Introduction

Theory chapters

Chapter 2: Literature review

- Basic innovation concepts
- Process innovation
- Open innovation
- Lifecycle perspectives
- Open process innovation
- Open process innovation from a lifecycle perspective

Chapter 3: Conceptual research framework

- Process innovation lifecycle
- Process innovation components
- Motivation for open process innovation
- Openness as search breadth and depth
- Routines and Capabilities

Methodology chapter

Chapter 4: Research methodology

- Philosophical assumptions
- Case-based research as a scientific method
- Rationale for conducting case-based research
- Case selection and overview
- Methods and tools for data collection
- Data analysis procedures
- Measures of scientific rigor

Analysis chapters

Chapter 5: Results of individual cases

Chapter 6: Cross-case results at different stages of the innovation lifecycle

Lifecycle stage 1 Ideation	Lifecycle stage 2 Adoption	Lifecycle stage 3 Preparation	Lifecycle stage 4 Installation
- Results - Discussion	- Results - Discussion	- Results - Discussion	- Results - Discussion
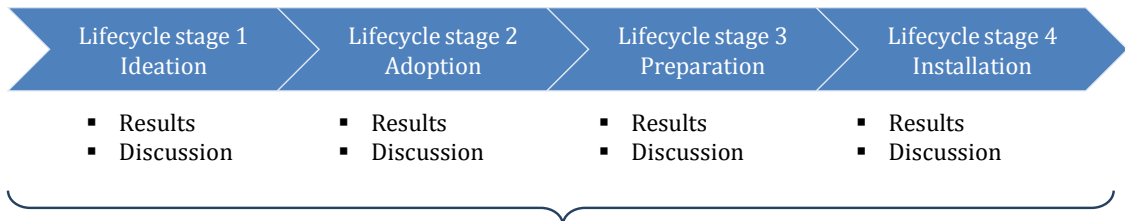
Chapter 7: General discussion and construct development

- External contributions to technological change
- Methodological guidance by management consultants
- The nature of further external contributions
- Capability deployment for open process innovation

Concluding chapter

Chapter 8: Concluding remarks: contributions, implications, and limitations

- Key contributions to theory
- Implications for managerial practice
- Limitations of the study and avenues for further research

Figure 1: Thesis structure

2   Literature review

The following chapter develops the theoretical background of this thesis. The purpose of the literature review is to identify gaps in the current body of knowledge on open process innovation from a lifecycle perspective. For this purpose key insights from different streams of literature are identified. Afterwards, it is assessed to which extent previous studies on open process innovation from a lifecycle perspective address these insights. This way the literature review provides a clear identification of the research gaps that the present thesis addresses. Following a brief introduction of basic concepts of innovation management research, the literature review therefore focuses on process innovation, open innovation, the innovation lifecycle, open process innovation, and finally open process innovation from a lifecycle perspective (Figure 2).
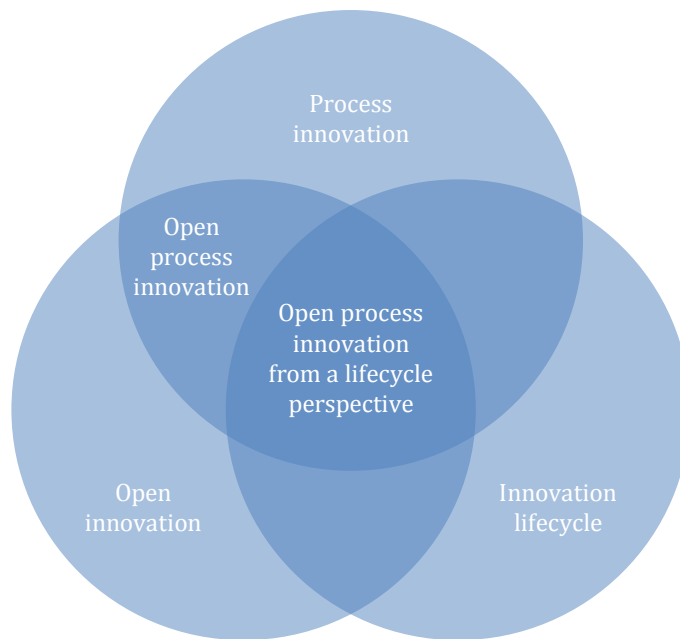
Figure 2: Key areas of literature review

2.1   Basic concepts of innovation management research

The Austrian economist Joseph Schumpeter is commonly credited as the first scholar to explicitly discuss the economic relevance of innovation. The "Schumpeterian view" argues that competition created through new products is far more important to economic success than marginal changes in prices of existing products (Trott, 2008). Today, a plethora of innovation literature exists in various academic disciplines. The wealth of literature and the abundance of

terminology often make it difficult to grasp an overview of relevant concepts and their meaning (Linton, 2009). To begin with, it is necessary to clearly distinguish innovation from invention. A discovery or development that is put to use and creates economic value for a company is an innovation. A discovery or development without application remains an invention (Garcia & Calantone, 2002). The Organization for Economic Co-operation and Development thus defines innovation as:

> ...the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations (OECD, 2005, p. 46).

As implementation presupposes development, two important streams of innovation can be distinguished: innovation as a process (lifecycle perspective) and innovation as an outcome (outcome perspective) (Crossan & Apaydin, 2010; Quintane et al., 2011). The distinction between these perspectives is critical to this thesis. The sections that follow provide an introduction to the literature on innovation with regard to innovation as a process and innovation as an outcome.

2.1.1 Innovation as a process

The lifecycle perspective on innovation focuses on "how" innovation is created (Crossan & Apaydin, 2010). From this perspective, innovation is typically defined as "the [activities involved in the] development and implementation of new ideas by people who over time engage in transactions with others within an institutional order" (van de Ven, 1986, p. 591). Research from a lifecycle perspective aims to conceptualize the sequence of organizational activities leading from idea generation to implementation (Quintane et al., 2011) and to identify the internal and external actors that participate in these activities (Crossan & Apaydin, 2010; Lager, 2011). Dominant innovation lifecycle concepts range from models with linear sequences of discrete activities to concurrent development, complex systems, and even chaotic approaches (McCarthy et al., 2006; Rothwell, 1994). Traditionally, the innovation process was regarded as the domain of a company's internal research and development (Chesbrough, 2003). More recently, an increasingly prominent stream of innovation research has begun to put a stronger focus on the locus of innovation by investigating the extent to which innovation processes occur across company boundaries (Chesbrough, 2006; Crossan & Apaydin, 2010).

The existing literature suggests that companies open their innovation process to external actors for a variety of reasons, such as: access to new markets and technologies, pooling complementary resources, and reduced lead times (Powell et al., 1996). In this context, innovation research focuses particularly on value creation through access to external

knowledge, technology, and commercialization channels (Chesbrough, 2003; Rothwell, 1991). As companies draw on external knowledge and external commercialization channels, the locus of knowledge creation (e.g. research), development (e.g. knowledge application, development), and commercialization (e.g. marketization) no longer need to be located within a single company (Gassmann & Enkel, 2004). As a result, various possible scenarios emerge, such as inbound, outbound, and coupled open innovation processes (West & Bogers, 2014). These provide companies with opportunities to refine and extend existing competencies and technologies (exploitation) and experiment with new opportunities for value creation (exploration) (March, 1991, p. 85).

Despite the promising opportunities of opening up the innovation process, this practice can also have negative effects on a company's innovation efforts. Inter-organizational interaction can impede innovation through complexity, loss of autonomy, and information asymmetry (Arias, 1995). Collaborative attempts at innovation often fail when companies are not able to absorb and retain new knowledge (Arias, 1995; Dussauge et al., 2000). In this respect a company's internal capabilities are critical to facilitate successful collaboration (Freel & Harrison, 2006). When collaboration with external partners is opportune, companies need "[...] substantial in-house capacity in order to recognize, evaluate, negotiate, and finally adapt the technology potentially available from others" (Dosi, 1988, p. 1132). Strong in-house research and development capacity can, for example, enable companies to better recognize, absorb, and exploit external knowledge (Cohen & Levinthal, 1990).

As companies increasingly engage in a variety of partnerships for technology development and commercialization, organizing the interaction within these partnerships is critical (Vanhaverbeke, 2006). While linkages with different external partners can contribute towards a company's innovativeness, Freel (2003) concludes that the phenomenon is more nuanced and only "certain types of cooperation are associated with specific types of innovation, involving certain firms, in certain sectors" (p.762). It is therefore critical at this stage to create a better understanding of innovation management across organizational boundaries (Pittaway et al., 2004).

2.1.2   Innovation as an outcome

The perspective on innovation as an outcome focuses on "what" is created (Crossan & Apaydin, 2010). From this perspective, innovation is usually defined as an invention "which has reached market introduction in the case of a new product, or first use in a production process, in the case of a process innovation" (Utterback, 1971, p. 77). Research on innovation as an outcome studies the outputs of the innovation process (Quintane et al., 2011). Inconsistent terminology presents

a particular challenge for the scholarly discourse on innovation outcomes (Garcia & Calantone, 2002; Linton, 2009). However, a common thread throughout the vast amount of literature on innovation is the notion of newness. To provide some orientation, Johanessen et al. (2001) thus distinguish between three questions to describe innovation outcomes:

1. What is new?
2. How new is it?
3. To whom is it new?

Crossan and Apaydin (2010) provide an extensive, systematic review of the innovation literature to establish different categories of innovation as an outcome. More specifically, they distinguish between the form, type, magnitude, and referent of innovation as an outcome. This classification can be consolidated with the three questions outlined above and therefore provides a strong tool to structure the innovation literature landscape (Table 2). Building on this classification the basic concepts underlying this thesis are outlined in the following.

Table 2: Newness dimensions and innovation outcome categories

Newness dimension	Innovation outcome category
What is new?	▪ Form of innovation ▪ Type of innovation
How is it new?	▪ Magnitude of innovation
To whom is it new?	▪ Referent of innovation

Adapted from Johannessen et al. (2001) and Crossan and Apaydin (2010)

Form of innovation as an outcome: The form of innovation outcome is commonly distinguished into product and process innovation, as well as service and business model innovation (Crossan & Apaydin, 2010). Which form an innovation outcome has may depend on the focal company's perspective. This becomes particularly noticeable with regard to product and process innovation (Hutcheson et al., 1995). Product innovation broadly refers to the introduction of a new product to the market. Process innovation in general terms describes the introduction of a new process within a company. New manufacturing technology is a product innovation from the perspective of a capital goods supplier, but a process innovation from the perspective of the company implementing it into its operations (von Hippel, 1988; Hutcheson et al., 1995).

Type of innovation as an outcome: The type of innovation can refer to technological and organizational innovation (Meeus & Edquist, 2006). Technological innovation describes either new technology or change enabled by technology. Organizational or managerial innovation is

change in "management practice, process, structure, or technique that is new to the state of art and introduced for further organizational goals" (Birkinshaw et al., 2008, p. 825). Many innovations involve both technological and organizational change (Reichstein & Salter, 2006; Womack et al., 1990). A similar but conceptually different interpretation of innovation type refers to technical and administrative innovation (Crossan & Apaydin, 2010). Technical innovation is conceptually broader than technological change (Damanpour & Evan, 1984) and refers to any change in a company's central activities (Bantel & Jackson, 1989). This includes changes to work organization in central activities. Administrative innovation occurs in the organization's social system (Damanpour & Evan, 1984). Typically this is narrowly defined around administrative issues and does not relate to primary activities. It therefore excludes change in work organization of primary activities, such as manufacturing (Birkinshaw et al., 2008) but covers technological change related to administrative tasks (e.g. new software in human resource management processes). The literature is not very consistent on the application of these terms. In fact, they are now often used interchangeably with technological and organizational innovation (Damanpour et al., 2009; Rowley et al., 2011). To avoid confusion the present thesis explicitly refers to technological innovation and organizational innovation, rather than technical and administrative innovation.

Magnitude of innovation as an outcome: Innovation magnitude describes the impact of change on a given status quo. Various concepts inform innovation magnitude, including most prominently radical and incremental change (Damanpour, 1988), architectural and modular change (Henderson & Clark, 1990), and systemic and autonomous change (Chesbrough & Teece, 2002; Gatignon et al., 2002). Adopting a systems perspective illuminates the differences between these concepts. Such a perspective views innovation outcomes as systems which comprise hierarchically structured subsystems and components that are linked together through meaningful relationships (Gatignon et al., 2002; Henderson & Clark, 1990; McCarthy et al., 2006). The innovation system itself can be part of a larger system into which it is implemented (Ackoff, 1971). Within this context radical innovations change individual components as well as the architecture in which they are linked together (Gatignon et al., 2002; Henderson & Clark, 1990). Incremental innovations involve improvements in individual components but maintain the same core concepts and the same architecture of linking the components (Gatignon et al., 2002; Henderson & Clark, 1990). Modular innovations involve new core concepts, yet maintain the same architecture (linkages between and components) as previous technologies. Architectural innovation is the "reconfiguration of an established system to link together existing components in a new way" (Henderson & Clark, 1990, p. 12). However, it is important to emphasize that a system is more than the sum of its parts as the interdependence of a system's elements gives rise to emergent features that characterize the system but not its individual parts

(Ackoff, 1997). The system is defined by its function. Therefore, a system can be divided structurally into sub-tasks but not functionally, as the emergent properties of a system get lost when it's taken apart (Ackoff, 1997; Maddern et al., 2014). Moreover, "systems [thinking] postulates that that actions taken in one subsystem affect the other subsystems as well as the suprasystem" (Zelbst et al., 2012, p. 331). With regard to such systemic impacts Chesbrough and Teece (1996) argue that some innovations are essentially autonomous while other are systemic. Systemic innovations incur or necessitate further changes in the system they are part of (e.g. the product or process), whereas autonomous innovations do not require any such changes. Against this background a further distinction can be made between core and peripheral subsystems (Gatignon et al., 2002). Change in core subsystems creates effects that may cascade throughout the entire system (e.g. product or process) because these subsystems are strongly interlinked with other subsystems. In contrast, because they are weakly coupled with other subsystems, change experienced in peripheral subsystems will only have a minor cascading effect (Gatignon et al., 2002).

Referent of innovation as an outcome: The referent is the benchmark for newness of innovation as an outcome (Crossan & Apaydin, 2010). Any discussion of innovation requires a point of reference to which newness relates and which constitutes the context into which the innovation is introduced (Gupta et al., 2007). Most commonly, the company perspective acts as the referent (Garcia & Calantone, 2002). Nonetheless, earlier studies have also used the whole world (Song and Montoya-Weiss, 1998; Kleinschmidt & Cooper, 1991), the market (O'Connor, 1998) or customers and users (Atuahene-Gima, 1995) as referents. The variety of possible referents means that the outcomes of innovative activities can be perceived as an innovation when measured by one referent, whereas it is an imitation or considered old when assessing it by another. Van de Ven (1986), thus states that "as long as the idea is perceived as new to the people involved, it is an innovation, even though it may appear to others to be an imitation of something that exists elsewhere" (p.592). Defining the referent from the outset is important, as differences in perspective directly influence the type, form, and magnitude of the impact observed (Crossan & Apaydin, 2010; Gatignon et al., 2002).

2.2 Process innovation

Process innovation is defined as the development and implementation of new or significantly improved organizational processes that are enabled by the use of new technology. This may include new machines and production equipment, as well as information technology. Furthermore, process innovation may involve changes to managerial practices and work organization (Carrillo & Gaimon, 2002; OECD, 2009). A process is a structured sequence of

activities that transforms an input into a specific output for a particular customer or market (Davenport, 1995). Processes describe how work is done within an organization rather than the output of that work (Davenport, 1995). Some processes relate to core or primary activities of the organization, while others have an enabling character. They facilitate the context in which primary activities are carried out but are not directly related to those activities. The CIM-OSA standard (AMICE, 1989) suggests a process categorization into "manage", "operate" and "support" processes. Operate processes directly address requirements of the external customer. Support processes include for example financial, personnel, facilities management and information systems provision activities and enable operate processes. Manage processes consist of direction-setting managerial activities that govern the overall strategic orientation of a company (Smart et al., 1999, p. 476). Similarly, Armistead and Machin (1997) distinguish operational processes, support processes, direction-setting processes and managerial processes, which can be grouped into the more general classes of core and enabling processes (Table 3).

Table 3: Different types of processes

Process type	Sub-type	Definition (Armistead & Machin, 1997, p. 894)
Core	Operational	"The way in which work gets done within an organization to produce goods or services"
Enabling	Support	"Enable the operational processes [and] are concerned with the provision of support technology, or systems, with personnel and human resource management, and with accounting management"
	Direction-setting	"Set the strategy for the organization, its markets, and the location of resources as well as managing change within the organization"
	Managerial	"Are to some extent superordinate to the other categories and contain decision-making and communication activities; entrepreneurial, competence-building and renewal processes … are managerial processes"

The following part of the literature review addresses process innovation as an organizational phenomenon. The main purpose thereof is to identify the underlying components that make processes a distinct form of innovation outcome. After an initial definition, the review is structured according to the different dimensions of innovation as an outcome as introduced previously (i.e. form, type, magnitude, and referent of innovation as an outcome). This derives from an understanding that innovation comprises multiple dimensions along which newness can be described.

2.2.1   Process innovation as a form of innovation outcome

Process innovation is one of the most prominent forms of innovation as an outcome. It is frequently contrasted with product innovation, although both are closely interlinked with each other (Damanpour, 2010). Several studies have investigated inter-relatedness and relative adoption rates of product and process innovation. Kraft (1990), for example, provides a study on the relationship between the adoption of product and process innovation in the manufacturing industries. He argues that companies could often only produce new products if they also implemented new manufacturing processes. Kraft provides empirical evidence that product innovation stimulates process innovation. Martinez-Ros (2000) presents significant evidence for the positive effect of process on product innovation in a similar setting as Kraft (1990). These findings suggest that complementarities exist between product and process innovation. New products may require new process, while advances in processes may enable new products. However, this does not mean that companies cannot adopt both forms of innovation independently. In a study on the relative adoption frequency of product and process innovation in the banking sector, Damanpour and Gopalakrishnan (2001) find that the rate and speed of product innovation adoption (e.g. ATMs, lock box, mutual funds) constantly exceeds the rate for process innovation (e.g. automated mortage generation, loan tracking systems). They suggest that the relative preference for product innovation results from a higher level of visibility which generates a perception of relevance for company success, larger revenues that can be realized through new products in contrast to comparably smaller cost savings through process innovation (cf. Pisano & Wheelwright, 1995), and greater attention towards product innovation champions (cf. Frost & Egri, 1991). Yet, Damanpour and Gopalakrishnan (2001) also find that high performing banks adopt product and process innovations more evenly than their lower performing competitors. This further corroborates the proposition that product and process innovation complement each other. Patterns of synchronous adoption among high performing companies have been reported across various industries (Ballot et al., 2015; Damanpour, 2010; Lim et al., 2006; Pisano & Wheelwright, 1995). In spite of the fact that process and product innovation complement each other, the literature identifies different drivers for both. The differences in the effects of determinants such as demand conditions, appropriability regime, sources of technological knowledge, market structure, company characteristics, strategy, etc. on the adoption of product and process innovation have been subject to important studies such as those by Cabagnol and Le Bas (2002) and Damanpour and Aravind (2006). The main drivers of product innovations are satisfying customer demand and accessing new markets (Damanpour & Aravind, 2006). In contrast, the key drivers for process innovation focus on internal performance improvements in relation to efficiency and effectiveness, including examples such as lead time reduction, decreasing costs, increasing production volume, as well as improvements

in sustainability, agility, controllability, flexibility, output quality, and coordination.(Aschhoff et al., 2008; Boer & During, 2001; Carrillo & Gaimon, 2002; Frishammar et al., 2011; Gerwin, 1988; Lu & Botha, 2006; OECD, 2009; Reichstein & Salter, 2006; Tornatzky & Fleischer, 1990).

In summary the literature provides evidence that product and process are distinct, yet highly interrelated and mutually enabling phenomena. Companies can adopt product and process innovation separately, in which case it is likely that the adoption rate of product innovation exceeds process innovation. The simultaneous adoption of both is likely to have positive effects on a company's performance. The drivers for product and process innovation differ. While product innovation is driven by market performance objectives, drivers for process innovation mainly relate to performance improvement objectives regarding a company's internal activities.

2.2.2   The magnitude dimensions of process innovation

Product and process innovation as forms of innovation outcome can be radical or incremental in magnitude. In the 1990s BPR emerged as a popular concept advocating radical redesign of business processes with focus on necessary tasks, desired outputs, and available technologies rather than maintaining old, inefficient processes (Davenport, 1993; Hammer & Champy, 1993; Hammer, 1990; Zairi & Sinclair, 1995). While BPR as a concept is less prominent today, it has its mark on operations management research and practice remains profound. Smart et al (2009) outline that : "today it is hard to find an organization that is explicitly trying to re-engineer its processes. On the other hand it is also hard to find a large organization that does not pay explicit attention to the design and management of its processes" (p. 493). Several seminal studies suggest that to remain competitive amidst changing market environments (i.e. technology maturity; demand heterogeneity) companies seek radical and incremental product and process innovations for different reasons and at different stages over an industry's lifecycle (Abernathy & Utterback, 1978; Adner & Levinthal, 2001; Anderson & Tushman, 1991; Utterback & Abernathy, 1975). The main proposition of these studies is that companies face a productivity dilemma between exploring opportunities for learning and radical innovation on the one hand, and exploiting existing capabilities through optimization and specific investments on the other (Benner & Tushman, 2003). While reusing existing knowledge and routinizing operations enables efficiencies, it impedes new knowledge creation and adaptation to changing market environments. Ambidexterity, dynamic capabilities, and business process management are central themes in the academic debate on resolving this productivity dilemma (Benner & Tushman, 2003; Eisenhardt & Martin, 2000; Raisch et al., 2009). In this context, the seminal work by Utterback and Abernathy (1975) (also: Abernathy & Utterback, 1978) on the adoption of radical and incremental product and process innovation throughout the industrial lifecycle in manufacturing industries suggests the following patterns (Figure 3).
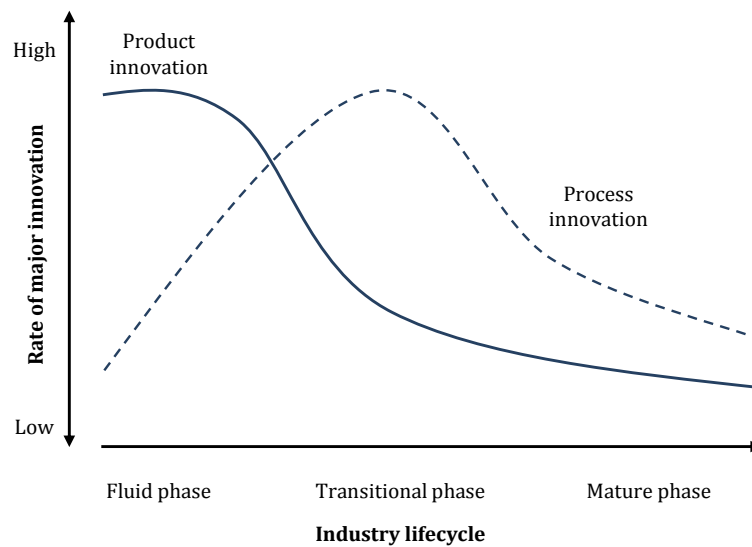
Figure 3: Industrial lifecycle model

Utterback and Abernathy (1975) distinguish three lifecycle stages: (1) the fluid phase; (2) the transitional phase; and (3) the mature phase

- In the *fluid phase* the industry is characterized by a high frequency of radical product innovation. Companies seek competitive advantage through increased product performance. Production processes are unstandardized, inefficient, and build on generic tools.

- In the *transitional phase* the industry matures and companies seek competitive advantage by maximizing sales and reducing costs. In this stage a predominant product design emerges and innovation efforts shift towards radical process innovation e.g. introducing new work organization and production methods.

- In the *mature phase* the industry has matured and competitiveness results from cost reduction and quality improvement. The mature stage is characterized by undifferentiated standard products, and specific investments in efficient, capital intensive and rigid production processes, thus incurring high costs for change. Products and processes are highly integrated. Innovation will be incremental for product and process. Only a major change in the available technology (technology discontinuity) will let the lifecycle start again (Anderson & Tushman, 1991).

2.2.2.1 Technical specialists and champions

The availability of internal process experts is an important determinant of successful incremental and radical process innovation (Dewar & Dutton, 1986; Ettlie et al., 1984; Germain,

1996). Ettlie et al. (1984) provide a seminal study on the determinants of innovation radicalness. They propose and test a model in which different combinations of organizational strategy and size, structure, and pre-innovative conditions lead to different innovation outcomes. Ettlie et al. find significant evidence that an aggressive technology policy strategy ("a preemptive, long-range strategy for technological innovation", p.684) promotes a high concentration of technical specialists, which they find to be the best predictor of radical process innovation adoption. Dewar and Dutton (1986) conduct a similar study in the manufacturing industries to replicate these findings. They define the concentration of technical specialists as the number and co-location of technical or engineering personnel within a company. Following Ettlie et al., (1984), Dewar and Dutton propose that a concentration of technical specialists creates a greater capacity to understand radical technological developments. A concentration of technical specialists would therefore positively affect the adoption of radical process innovation, but have no effect on the adoption of incremental process innovation. Contrary to their hypothesis, Dewar and Dutton find that the concentration of technical specialists was significantly positively associated with the adoption of both radical and incremental process innovation. Similarly, Germain (1996) investigates the determinants of radical and incremental process innovation adoption among US manufacturing companies. Germain finds significant support for the hypothesis that specialization ("number of areas one or more full time specialists deals with", p.126) is positively related to the adoption of incremental process innovation as well as radical process innovation. The empirical evidence thus suggests that the concentration of technical specialists enables companies to develop the capacity to understand new process related information and facilitate its internal application (Cohen & Levinthal, 1990; Dewar & Dutton, 1986), which in turn has a positive effect on the adoption of incremental and radical process innovation. Furthermore, the concentration of technical specialists promotes the existence of technology champions (Ettlie et al., 1984), i.e. "an individual who is intensely interested and involved with the overall objectives and goals of the project" (Chakrabati, 1974, p. 58). Technology champions typically have the hierarchical power or a strong reputation for technological expertise ("evangelist") to promote radical innovation against internal opponents despite the potential risks involved in such changes (Herrmann et al., 2006; Meyers et al., 1999).

2.2.2.2 Organizational characteristics

Organizational characteristics also have implications for the adoption of radical and incremental process innovation. Dewar and Dutton (1986) find no significant support for their initial hypothesis that organizational complexity (number of different occupational specialties) is positively associated with the adoption of radical process innovations. They conclude that the concentration of technical specialists is more relevant for the adoption of radical process innovation than the breadth of specialists and areas of expertise. Indeed, Ettlie et al (1984) find

that large organization size promotes complex structures and a high degree of formalization, which in turn makes it more likely for companies to adopt incremental process innovation rather than radical innovation. In contrast, Dewar and Dutton (1986) find that size has a positive association with radical innovation. It seems contradictory that large size promotes radical process innovation, while also creating complexity and formalization which impede the adoption of radical innovation. Ettlie et al (1984), however, show that along with structural complexity and a high degree of formalization, decentralized organizational structures support the adoption of incremental process innovations (cf. Herrmann et al., 2006). Centralization and informal structures, in contrast, support radical process innovation adoption (Ettlie et al., 1984). This implies that large size generally provides an infrastructure for radical process innovation (e.g. through concentration of technical specialists, available resources, external connections). Nevertheless adequate organizational design and managerial practice to adapt to different innovation contingencies are necessary for these potentials to be realized successfully (see Appendix 1: Characteristics of large companies for more information on the characteristics of large companies).

2.2.2.3 Systemic nature of process innovation

Organizational processes can be viewed from a systems perspective, as, by definition, they exist as a set of interlinked components that work towards a specific common goal in their capacity as sub-systems of the broader organizational system to which they belong (Batista et al., 2008; Kurkkio et al., 2011; Smart et al., 1999). The innovation management literature typically understands processes as comprising various tools, machines, people, and physical infrastructure across the organization that are inter-connected in specific relationships to enable a flow of material and immaterial goods to produce specific outputs (Ettlie & Reza, 1992; Kurkkio et al., 2011; Tornatzky & Fleischer, 1990). Chesbrough and Teece's (2002) original discussion of systemic and autonomous innovation refers to both products and processes. They present lean manufacturing as an example of systemic process innovation, as it "requires interrelated changes in product design, supplier management, information technology, and so on" (p.6). However, they do not discuss autonomous process innovations. Process innovation can be autonomous if the implementing company's process architecture is highly modular (Robertson et al., 2012). Modular process architectures break company's key activities down into explicit, formal, codified routines with standardized interfaces and minimal interdependencies (Worren et al., 2002). In such an architecture process innovation may be relatively autonomous. Robertson et al. (2012), however, doubt that in practice full modularity is desirable or achievable. It is more likely that process innovation always entails some degree of systemic impact. As a result, process innovation introduces change to various components as well as their linkages (Gopalakrishnan et al., 1999; Gopalakrishnan & Bierly, 2001). Systemic

impact thus results either "from the introduction of conversion processes based on unfamiliar technical principles (e.g. thermal forming instead of mechanical shaping of metal parts), or [from] unfamiliar relationships among process operations, (e.g. integration of discrete manufacturing steps into a continuous production flow)" (Tyre & Hauptman, 1992, p. 303). Such impact can render established systems obsolete and drive the reformulation of existing organization manufacturing or administration systems, functions, structures, and mental models (Gerwin, 1988; Tyre & Hauptman, 1992). The systemic nature of process innovation is a critical management challenge (Kurkkio et al., 2011; O'Hara et al., 1993; Voss, 1992). Planning and executing the integration of a new process with the existing organization without disrupting current operations can be a delicate issue during the development and implementation of new processes (O'Hara et al., 1993). Unexpected changes to the process design may lead to substantial costs, effort, and additional development time if they require the revision of earlier decisions and designs (Terwiesch and Loch, 1999). Several authors therefore recommend that systemic considerations should already inform the investment decisions companies make when selecting process candidates (Jensen & Westcott, 1992; Voss, 1992). Moreover, Kurkkio et al., (2011) show that considering the integration of new processes with existing technologies, operating conditions, and capabilities is critical even during the very early, "fuzzy front-end" of process development.

The literature on business process management particularly advocates continuous and holistic approaches to managing processes "end-to-end" (Smart et al., 2009). The nature of end-to-end integration, however, implies basic systemic characteristics, such as emergent properties and hierarchical structures, rather than merely extended process boundaries (Batista et al., 2008; Maddern et al., 2014; Smart et al., 2009, 1999). Process boundaries are difficult to determine, as processes not only extend across various tasks, functions, or even departments, but also comprise complex, non-linear knowledge flows. Moreover, processes are neither discrete nor independent. They comprise interdependencies with other processes and involve human actors as well as technologies. A holistic perspective on a company's operational system is therefore critical to prevent sub-optimization and approach flawless process integration (Maddern et al., 2014; Smart et al., 1999). In this context process-related change becomes a challenging managerial task (Maddern et al., 2014; Smart et al., 2009). From a process innovation perspective this means that new processes have to be integrated with the existing organizational system. It is unlikely that changes within this system are entirely modular (Robertson et al., 2012). Instead, change is likely to emerge from non-linear causal interaction that need to be discovered and are difficult to anticipate. Process innovation therefore implies systemic impact. The integration of new processes within a system may require adapting the existing system. Likewise, integration may equally enforce structures on the new process itself.

In summary the concentration of technological experts and the existence of a powerful technology champion are necessary to drive investment in new technology to facilitate (radical) process innovation. Moreover substantial managerial effort is necessary to overcome organizational complexity when seeking to realize radical process innovation in large companies and centralization may be helpful to overcome resistance to change in such situations. Finally, previous literature on process innovation and process management suggests that companies have to account for the impact that new processes may have on the organizational system.

2.2.3 Different types of process innovation

Process innovation is a broad phenomenon that typically comprises technological as well as organizational change (Reichstein & Salter, 2006). Nevertheless, the innovation management literature distinguishes between technological and organizational process innovation for analytical purposes. Technological process innovation refers to process change enabled by upgrades or replacements of hardware manufacturing equipment or (software) information technology. Organizational process innovation comprises new ways of structuring work within the company (Carrillo & Gaimon, 2002; Edquist et al., 2001; Meeus & Edquist, 2006). The following sections review the literature on technological and organizational aspects of process innovation, their adoption, and mutual adaptation.

2.2.3.1 Technology related aspects of process innovation

Technology is broadly defined as applied knowledge that enables the transformation of inputs into outputs (Daft, 2004). In the context of process innovation this includes hardware, such as new processing machinery, industrial robots, and IT-infrastructure, as well as software (Schallock, 2010). The literature documents various reasons why companies adopt new process technologies. New production technology can reduce yield loss and therefore lower production costs, while new software technology can enable operations to be monitored more precisely in terms of output quality (Carrillo & Gaimon, 2002). Zelbst et al. (2012), for example, show that the use of radio-frequency-identification technology in inventory management processes can improve manufacturing efficiency and increase customer satisfaction. Different types of technologies exist. Dodgson et al. (2006) distinguish between three generic types of technology and how they benefit the innovation process (Table 4).

Table 4: Different types of technology

Type	Definition	Benefits	Examples
Information and communication technology (ICT)	Enable the provision of a ubiquitous digital infrastructure to facilitate inexpensive, rapid, and secure storage and transfer of information and data	Improve speed, processing power, connectivity, and physical interfaces, enable cost reductions and collaborative or concurrent development work	▪ World wide web ▪ Computers and servers
Operations and manufacturing technology (OMT)	Facilitate implementation and operation of new processes Enable, automate, standardize, and control, the flow of information, components, and products in production Comprise combinations of machines, robots, and software to manage coordination of information	Process, make, and assemble varieties of products predictably, quickly, and cheaply Enable increasing reliability, flexibility, and accuracy, and reducing prices and costs in production	▪ Computer Numerical Control ▪ Computer Aided Manufacturing ▪ Computer Aided Manufacturing ▪ Flexible Manufacturing System ▪ Enterprise Resource Planning Systems
Innovation technology	Provide the means to assist companies in their innovation activities Bring together multiple inputs into the innovation process	Facilitate economies of effort and specification of innovations Provide opportunities to explore new options, collaborate, and "play" with design and different solutions Ensure that ICT and OMT are used to maximum effect	▪ Modelling and simulation ▪ Visualization/virtual reality ▪ Rapid prototyping

Table adapted from visual and definitions in Dodgson et al. (2006, p. 8)

The introduction of new technology confronts companies with the "relative novelty, sophistication … technical features" (Tyre & Hauptman, 1992, p. 303). Technology can be new to the world, industry, application, company, plant or department (Jensen & Westcott, 1992). Companies can acquire new technology or technological components through internal development, from external sources, or a combination of both (Cooper, 2007; Lager, 2011; Stock & Tatikonda, 2004). Depending on the problem at hand, companies may seek the acquisition of standardized, off-the-shelve technologies or the development of new, proprietary solutions. In any case, the exploitation of a new technology's performance requires that it fits its context of application (e.g. technological infrastructure, support system, operator capabilities, etc.)

(Leonard-Barton & Deschamps, 1988; Rönnberg-Sjödin, 2013). Bendoly and Jacobs (2004), for example, document that the alignment of new enterprise-resource-planning (ERP) systems with existing internal processes, operations and performance objectives is "crucial to perceived ability to deliver orders on time and to general satisfaction with the ERP solution…" (p. 114).

New technology may to some extent build on existing knowledge and competencies but often requires more or less drastic changes to existing skills and structures (Tyre & Hauptman, 1992). As the consequences of new technology adoption are often not immediately comprehensible to developers and operators, process innovation may lead to equivocality (Frishammar et al., 2011) and uncertainty (Gerwin, 1988; Stock & Tatikonda, 2004). Equivocality refers to "the existence of multiple and conflicting interpretations among project participants" (Frishammar et al., 2011, p. 551). It is characterized by confusion, and a lack of consensus and mutual understanding and may be the result of the participants' different Weltanschaungen. Uncertainty refers to a negative "difference between available information and the information needed to complete a task" and is characterized by a lack of relevant information (Frishammar et al., 2011, p. 551). In the context of technological process innovation, Gerwin (1988) distinguishes between technological uncertainty (related to determining technological performance specifications), financial uncertainty (related to forecasting returns on technology investments), and social uncertainty (related implications of technology introduction for internal stakeholders). Equivocality and uncertainty also depend on the new technology's attributes (Tatikonda & Stock, 2003). The literature advances a large number of attributes by which technological innovation can be characterized. Rogers (2003) suggests the following attributes to describe technological innovation: relative advantage, complexity, compatibility, observability, and trialability. Tornatzky and Klein's (1982) list of the most frequently cited innovation attributes also includes cost, communicability, divisibility, profitability, and social approval. The content of a technology's attributes affect its transfer and adoption (Bogers, 2011; Rogers, 2003; Tatikonda & Stock, 2003). Stock and Tatikonda (2004), for example, develop and empirically validate a framework to show how technological novelty, complexity, and tacitness determined the degree of uncertainty involved in technological product and process innovation projects across various industries and how this affects the level of engagement with the suppliers of this technology (this is further discussed in section 2.3.4.4).

2.2.3.2   Organizational change related aspects of process innovation

Organizational change as an integral component of process innovation broadly refers to new ways of organizing work activities and structures within a company (Edquist et al., 2001). In this context, organizational innovation includes the development and implementation of change to existing processes, organizational structures, administrative systems, and management methods (Carrillo & Gaimon, 2002; Damanpour & Aravind, 2012). Parikh and Joshi (2005), for example,

describe organizational process innovation in their study of the way a utilities company restructured the organization of its purchasing processes in terms of participation, formalization, and centralization to reduce the internal transaction costs for small purchases.

The innovation management literature offers various definitions of organizational innovation (Camisón & Villar-López, 2014; Hervas-Oliver & Sempere-Ripoll, 2015). At times, organizational innovation is used to describe any innovation within an organization (Birkinshaw et al., 2008). Other authors propose very specific definitions or subsume different definitions under the umbrella term of organizational innovation. This can cause definitional confusion. For example, literature on organizational innovation is often used interchangeably with administrative innovation (Damanpour et al., 2009; Rowley et al., 2011). Administrative innovation, however, deals with "…management issues such as staffing and employee surveys, strategic planning, compensation systems, and training programs…" (Bantel & Jackson, 1989, p. 120) and does not directly relate to a company's primary work activities (e.g. manufacturing operations) (Damanpour & Aravind, 2012; Linton, 2009). Administrative innovation, therefore, ignores the fact that process innovation may also require organizational change in the operations and procedures that directly relate to a company's primary work activities (Birkinshaw et al., 2008; OECD, 2005). Organizational innovation, on the other hand, denotes a broader field of application. Edquist et al. (2001) for example state: "…organizational process innovations are new ways to organize business activities such as production or R&D and have no technological elements as such … Examples of recent organizational process innovations are just-in-time production, TQM, and lean production" (p.15). To maintain an illustrative distinction between technology and work organization the present thesis uses the term "organizational innovation" but specifically refers to changes regarding work organization in context of process innovation (see also framework development in Chapter 3).

Organizational innovation is relatively difficult to legitimize as its purpose and consequences are often not immediately evident to all stakeholders (Damanpour & Aravind, 2012). Birkinshaw et al. (2008) identify three main reasons that make organizational innovation a particularly challenging task for many companies: (1) organizational innovation involves significant amounts of tacit knowledge and is difficult to observe, define, and identify; (2) many companies lack expertise in developing and implementing organizational innovation; and (3) making changes to the existing organization typically causes ambiguity and uncertainty amongst stakeholders. Moreover, organizational innovation often implies changes in multiple functions or departments within a company (Gopalakrishnan et al., 1999; Kurkkio et al., 2011). Disagreements between different stakeholder groups, such as operators and operations managers, process innovation task forces, and higher-level decision makers cause further ambiguity and conflict (Birkinshaw et al., 2008; Gerwin, 1988; Leonard-Barton & Deschamps, 1988; Leonard-Barton, 1988).

Nonetheless, gaining both top-management commitment as well as bottom-up acceptance is pivotal for successful of process innovation, especially in the context of powerful manufacturing departments (Meyers et al., 1999; Shields & Malhotra, 2008). Gerwin (1988) suggests that in particular the potential alteration of roles, power, and status and the discrepancies in expectations and requirements across different stakeholder groups lead to intra-organizational conflict during process development and implementation. Gerwin outlines how conflict over decision making authority emerged between the accounting department and shop floor management during the development and implementation of a flexible manufacturing system. Resolving conflict and discrepancies is a particular challenge for large, complex organizations which have to manage change across a large number of different, and often very independent functions or departments (Pavitt, 1991; Vossen, 1998). Coordination thus emerges as a key challenge in developing and implementing organizational aspects of processes innovation.

2.2.3.3 Congruency between technology and organization

The distinction between technological and organizational process innovation is useful for analytical purposes and highlights the dual nature of process innovation. Yet, process innovation typically entails the adoption of both technological and organizational innovation (Reichstein & Salter, 2006). Edquist et al. (2001) state that "...organizational and technological changes are closely related and intertwined in the real world and organizational change is often a requirement for successful technological process innovation..." (p.16). As with innovation management, the operations management literature also emphasizes that process design comprises the development and implementation of technology as well as operators, tasks, roles, procedures, and work organization (Slack et al., 2013). While technological and organizational process innovation can have positive effects on organizational performance independently of each other (Georgantzas & Shapiro, 1993), the empirical literature typically agrees that companies can exploit synergies from the dual adoption of complementary technological and organizational innovation (Battisti & Stoneman, 2010; Ettlie & Reza, 1992; Georgantzas & Shapiro, 1993). Companies, especially those in the manufacturing industries, seek to improve plant competitiveness by simultaneously upgrading process technologies and introducing changes to existing organizational practices (Jayanthi & Sinha, 1998). Lean manufacturing is one of the most illustrative examples of the complementarity between technological and organizational change for process innovation (Womack et al., 1990). The reduction of move and wait of parts in lean manufacturing processes, for example, is achieved through restructuring the technological production system but can only be sustained when complemented by changes in shop floor work organization and employees' operating capabilities (White & Ruch, 1990). In this context, Ettlie (1988) coined the term "synchronous innovation" to describe the dual adoption of technological and organizational change. Recent research picks up the topic of the

complementary effects of technological and organizational innovation and suggests that technological process innovation requires organizational innovation to cope with managerial challenges of technology development and implementation (Hollen et al., 2013). Likewise, Hervas-Oliver and Sempere-Ripoll (2015) substantiate the evidence for the benefits of integrating technological and organizational change in process innovation. In particular, they provide evidence from large scale survey data to suggest that the effectiveness of technological process innovation and organizational innovation are mutually reinforcing. Hervas-Oliver and Sempere-Ripoll conclude that companies can achieve significant performance improvements by combining efforts of technological and organizational innovation. However, it remains debatable to what extent technological and organizational change can actually be developed concurrently (Damanpour & Evan, 1984). Organizational change tends to be less observable, less trialable, and relatively more complex, thus making it more time consuming to plan and implement than technological change (Damanpour & Evan, 1984). Against this backdrop, it may be suggested that a continuous focus on organizational change is necessary to sustain the fit between technology and organization once a new technology is in operation (Voss, 1988).

Process innovation involving technological and organizational change presupposes that technology and organization are congruent, i.e. fit with each other. Congruency is a necessary condition for leveraging potential complementarities in the adoption of technological and organizational change (Hervas-Oliver & Sempere-Ripoll, 2015). Ettlie et al. (1984) define congruency as the fit between "...a particular innovation and an organization based on the opinion of key organization members of the technology on several important attributes..." (p.685). Gerwin (1988) reports that for process innovation involving advanced manufacturing technology it is not only necessary to develop and install new technology but also to develop relevant infrastructure to enable the new process. According to Gerwin, this includes the implementation of new skills, systems, procedures, and structures among the operators working with the new processes. Cantamessa et al. (2012) study the adoption of product-lifecycle-management (PLM) technology to innovate product development processes. They highlight that achieving a fit between the PLM technology and the broader IT support infrastructure, job performance requirements, and the deployment of training programs to develop operator skills were critical objectives to develop and implement new, PLM-driven product development processes successfully (Cantamessa et al., 2012). In this context it may even be necessary to adjust the training and support to the different demands of various user groups within the company (e.g. early adopters and later adopters; young and old employees, etc.) (Cantamessa et al., 2012; Leonard-Barton & Deschamps, 1988). The different notions of congruency identified by the studies above indicate that there is no single form of congruency that caters to all innovation projects. As suggested by contingency-theoretical perspectives, the most appropriate

solution depends on the specific circumstances in which change is implemented and requires contextual responses (Donaldson, 2001; Lawrence & Lorsch, 1967). The fit between technology and organization is therefore contingent on the specific circumstances of the individual company and innovation project within that company. Achieving a unique fit between technology and organization may thus enable a company to distinguish itself from competitors using similar technologies that can be acquired on the market (Hatch & Mowery, 1998). At the outset of an innovation project, however, new technology is unlikely to fit with existing organizational infrastructure and processes, making mutual adaptation a necessary prerequisite for process innovation (Tyre and Hauptman, 1992). In this sense mutual adaptation refers to the reconfiguration of technology to fit with the organization and vice versa (Leonard-Barton, 1988). Mutual adaptation is necessary to overcome various misalignments between the technology and the organization into which it is introduced, including misalignments between the technology and the original expectation towards it based on the sophistication of the technology and the environment in which it is implemented; the technology and the way it is delivered to the organization, either its physical form or the way it is introduced; and the expected consequences of the technology on task performance as expected by different organizational stakeholders (Leonard-Barton, 1988). To overcome misalignments, companies thus face the particular challenge of having to "… [modify and reinvent] both the new technology and relevant aspects of the receiving organization… [which] may include adapting manufacturing routines, procedures, and skills…" (Tyre & Hauptman, 1992, p. 304). Indeed, Majchrzak et al. (2000) show that in principle change can occur in all structures relevant to process innovation. Company-specific circumstances may, however, constrain the extent to which certain structures can be changed. Majchrzak et al. refer to a virtual product development team with highly malleable structures. Large, mature manufacturing companies may have more rigid structures (see Appendix 1: Characteristics of large companies). In such organizations it may be difficult to make further changes once the technology has been installed, routines become established, and the pressures of production, costs of changes, decreasing enthusiasm, impede opportunities for change (Tyre & Hauptman, 1992). A common thread in the adaptation literature is the focus on adaptation during and after technology implementation. This is important because a lot of learning occurs by doing, which further shapes the technology and its operators (Von Hippel & Tyre, 1995). Nevertheless, problem-solving may occur long before the introduction of a new process (Pisano, 1996). Furthermore, it is significantly easier and cheaper to plan and carry out change prior to installation (Gerwin, 1988; Tyre & Hauptman, 1992). While implementation indeed marks a critical point for the management of process innovation (Voss, 1992), the early stages of process development are equally important as they determine and prepare the input for later stages of the innovation lifecycle (Gerwin, 1988; Kurkkio et al., 2011;

Lager, 2011). As such, they provide an opportunity to deliberately alter technology and organization to reduce misalignments between them.

2.2.4 Different referents of process innovation

Process innovation is typically put to application within an organization rather than on the market (Huang & Rice, 2012; Lager, 2000). As a result, it is most compelling to assess process innovation from the perspective of the adopting company (Crossan & Apaydin, 2010). Damanpour and Aravind (2006) even suggest that the company as a referent clearly distinguishes process from product innovation. An exception in this respect is the study by Reichstein and Salter (2006) on the sources of process innovation in UK manufacturing industries. Reichstein and Salter use the referent to distinguish between radical and incremental process innovation. They suggest that radical process innovations are new to the industry, whereas incremental innovations are imitated from a pioneering company. A problem with this approach is that something radically new to one company may only constitute an incremental change from the perspective of another. Moreover, process innovation typically includes tacit and systemic, company-specific knowledge (Gopalakrishnan et al., 1999; Gopalakrishnan & Bierly, 2001). This makes it difficult to simply imitate process innovation. Even the intended imitation of process innovation may still present a company with radical change. Furthermore, process innovations are much less observable than other innovation outcomes. Even for managers who are generally well informed about developments in their industry, it is difficult to assess the newness of their company's process innovation at the industry level (Bloodgood & Bauerschmidt, 2002). Against this backdrop, the company as referent for the investigation of process innovation promises most relevant and meaningful insight into the management of open process innovation.

2.2.5 Conclusion

The literature review in the previous sections adopted a multi-dimensional perspective on innovation as an outcome and discussed process innovation with regard to the most important outcome dimensions (i.e. form, magnitude, type, and referent). This led to the identification of several key insights, as shown in Figure 4.

Process innovation:
- Is driven by internal operations improvement objectives; comprises low outside visibility; can occur independently or conjointly with other forms of innovation
- Requires top-management support and bottom-up acceptance and is positively affected by presence of technical specialists and influential champions
- May be difficult to coordinate within large, complex organizations
- Involves technological and organizational change for mutual adaptation of new technology and existing organization
- Requires planning and coping with impact on broader organizational system
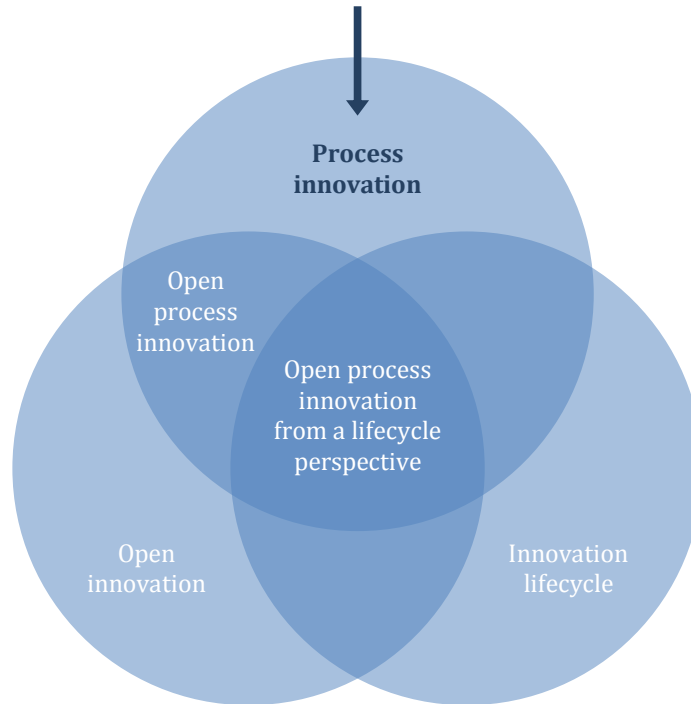
Figure 4: Key insights from process innovation literature

2.3   Open innovation

Open innovation is a management paradigm which posits "that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as [they] look to advance their technology" (Chesbrough, 2003, p. xxiv). Open innovation is defined as "the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively"(Chesbrough, 2006, p. 1). This part of the literature reviews the drivers for the adoption of open innovation, different open innovation processes, the relevance of different types of external partners, the measurement of openness, as well as the relevance of absorptive capacity for open innovation.

2.3.1 Towards open innovation

Chesbrough (2003) proposes the following narrative to illustrate and reflect the emergence of open innovation as a dominant paradigm for the efforts companies' make to innovate: open innovation replaced the closed innovation paradigm, which regarded the management of innovation processes as the domain of companies' internal research and development. This view derived from the high concentration of knowledge and scientific expertise within a relatively small number of large companies throughout most of the twentieth century. Due to their advanced situation, these companies neither could nor would rely upon the quality and availability of innovative input from external sources. The growing number and increasing mobility of highly educated, experienced, and skilled people at the end of the twentieth century made it progressively more difficult for large companies to maintain proprietary access to innovative ideas and expertise. Moreover, the unprecedented availability of venture capital encouraged entrepreneurs to develop and commercialize ideas on their own. As a result, knowledge and technology dispersed to a wide range of companies of all sizes and across various industries and locations; rendering the underpinnings of the closed innovation paradigm obsolete. The open innovation paradigm suggests that organizational boundaries have become permeable and that research, development and commercialization activities cross organizational boundaries and foster knowledge and technology transfer between different organizational and private actors.

Different drivers for the shift towards open innovation: Previous literature also documents various drivers for the initial shift towards more permeable company boundaries. These include, for example, growth and exploration of external technologies and complementary assets, as well as cost reduction and risk mitigation through external research and development (Chesbrough & Crowther, 2006; Gassmann et al., 2010). Few studies explore the process by which the transition towards open innovation unfolds. Chesbrough and Crowther (2006), for example, suggest that open innovation is typically implemented as a top-down decision and constitutes an additional strategic layer to the existing organization. Chiaroni et al. (2010) provide a more specific study on the transition from closed to open innovation. They document how companies in mature industries move from closed to open innovation by undergoing change in four main dimensions (inter-organizational networks, organizational structures, evaluation processes, and knowledge management systems). They suggest that a company's performance objectives along these dimensions change as the company recognizes the relevance of becoming more open, starts implementing change, and finally institutionalizes open innovation. In a further study Chiaroni et al. (2011) consolidate their earlier findings and show that in contrast to earlier research by Chesbrough and Crowther (2006), open innovation is not just layered on top of existing processes. Instead they find that the adoption of open innovation fundamentally changes

organizational processes and the metrics by which innovation projects are evaluated within an organization. They conclude that open innovation leads to systemic organizational transformation towards the strategic emphasis on leveraging external knowledge and technology in the innovation process. Against this background, Mortara and Minshall (2011) argue that companies may nevertheless follow different paths in their adoption of open innovation, given their specific circumstances, such as innovation needs, prior experiences with collaboration, and organizational culture.

The relevance of open innovation as a concept: Open innovation as a concept has experienced rapid proliferation in the academic literature (Gassmann et al., 2010; Huizingh, 2011; West et al., 2014). Yet, several authors have raised concerns that open innovation is merely "old wine in new bottles" and that the transformation from closed to open approaches is an artificial one (Trott & Hartmann, 2009). Indeed, collaboration between companies and external partners is not new and has been both practiced and studied for decades as West and Bogers (2014) lay out in an extensive literature review. The drivers of inter-organizational collaboration for example have been extensively discussed from various theoretical perspectives (e.g. strategic management, transaction cost economics, international business, relational view of the firm). Typically they include risk sharing, obtaining access to new markets and technologies, speeding products to markets, and pooling complementary resources (Powell et al., 1996). More specifically, earlier innovation research already emphasized that collaboration as a lever for innovation was largely driven by the ambition of gaining access to external sources of knowledge and technology (Rothwell, 1991). In their seminal study on the purpose and structure of networks in the biotechnology industry, Powell et al. (1996), for example, find that the high pace of technological development made it impossible for single companies to possess every capability required to successfully innovate in isolation. Powell et al. (1996) conclude that in industries where knowledge is the key to competitive advantage but widely dispersed among a number of actors, "the locus of innovation is found in a network of inter-organizational relationships" (p.196). In effect open innovation builds on a variety of antecedent streams of literature that are not specifically labelled "open innovation" but nonetheless provide insight on key issues of research under the open innovation umbrella (Badawy, 2011; Trott & Hartmann, 2009). In a systematic literature review, Dahlander and Gann (2010) documented that studies on absorptive capacity (Cohen & Levinthal, 1990), complementary assets (Teece, 1986), and exploration and exploitation (March, 1991) were among the most cited in publications on open innovation. Nonetheless, the terminology open innovation introduces several advantages as listed in the below:

- The emerging literature on open innovation increases awareness and encourages companies to approach collaboration more systematically (Mortara & Minshall, 2011).

- Open innovation assigns a single term to a variety of collaborative arrangements and fields of research which offers an opportunity for integrated theory development (Huizingh, 2011).

- Open innovation emphasizes the collaboration with various external partners, while previously different disciplines narrowly focused on specific external partners (Bahemia & Squire, 2010).

- Open innovation emphasizes openness for technology flows from within the company to the external environment and vice versa (Huizingh, 2011).

- Openness may take various forms along the analytical spectrum from closed and open. This provides great opportunities to investigate the management of different openness configurations (Dahlander & Gann, 2010; Lazzarotti & Manzini, 2009).

2.3.2 Inbound, outbound, and coupled open innovation processes

Open innovation calls into question traditional perspectives of company boundaries (Lichtenthaler & Lichtenthaler, 2009). The permeability of organizational boundaries enables the purposive flow of ideas, knowledge, and technology into and out of the company at different stages of the innovation lifecycle (Chesbrough, 2006). This perspective de-couples the locus of knowledge creation, from the locus of development, and the locus of commercialization (Gassmann & Enkel, 2004). In this context, the open innovation literature distinguishes between inbound and outbound open innovation (Chesbrough & Crowther, 2006; Gassmann & Enkel, 2004; Lichtenthaler & Lichtenthaler, 2009) (Figure 5).
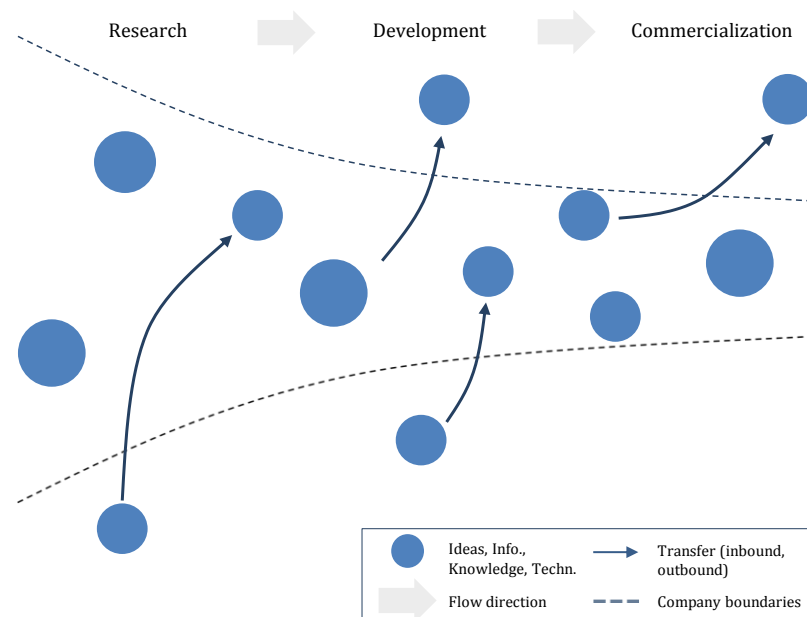
Figure 5: Open innovation funnel

The inbound-outbound dichotomy has its roots in the exploration-exploitation framework (Bianchi et al., 2011; March, 1991). Exploration is "the pursuit of knowledge of things that might come to be known" and exploitation is "the use and development of things already known" (Levinthal & March, 1993, p. 105). Exploration refers to knowledge generation, while exploitation refers to knowledge application (Grant & Baden-Fuller, 2004). Exploration refers to searching for business opportunities and new technologies, whereas exploitation refers to putting to practice and generating value from known technologies (Koza & Lewin, 1998; Simard & West, 2006). Companies can explore new knowledge which lies outside their boundaries or they can create knowledge internally. Equally, companies can exploit their knowledge by internal means, or through external channels (Lichtenthaler & Lichtenthaler, 2009). Against this background Bianchi et al. (2011) suggest that "...inbound open innovation serves the purpose to improve the firm's exploration capabilities in innovation management, whereas outbound open innovation is very much related to the exploitation of the firm's current basis of knowledge and technologies" (p.24).

Inbound processes: Inbound open innovation describes an outside-in process, in which an idea, knowledge, or technology is transferred from the external environment into the company (Gassmann & Enkel, 2004). Relevant knowledge sources in a company's environment include universities, consultants, competitors, suppliers, or customers (Reichstein & Salter, 2006; Terjesen & Patel, 2014). Mechanisms for inbound innovation include, for example, technology in-licensing, acquisition or collaboration and joint development (Spithoven et al., 2011). Inbound open innovation is an opportunity to explore new knowledge and complement internal research and development (Chesbrough & Crowther, 2006; Gassmann & Enkel, 2004). Outside-in knowledge transfer is particularly useful when a company lacks internal resources, when superior external technology is available or when market barriers are low and technology transferability is high (Gassmann & Enkel, 2004). To perform and benefit from inbound open innovation, companies need the capability to recognize and absorb external knowledge (Lichtenthaler & Lichtenthaler, 2009; Spithoven et al., 2011). A hindrance to inbound open innovation can be the "Not-Invented-Here" syndrome (Chesbrough & Crowther, 2006; Gassmann et al., 2010; West & Gallagher, 2006). The "Not-Invented-Here" syndrome describes the phenomenon of organizational resistance against the adoption of externally sourced knowledge and technology and the detrimental performance aspects it can yield (Katz & Allen, 1982).

Outbound processes: Outbound open innovation describes an inside-out process, by which companies transfer ideas, knowledge, or technology across the organizational boundaries into the external environment (Gassmann & Enkel, 2004). Through outbound open innovation companies exploit internal developments through external business models that are better

suited for commercialization than the companies' internal paths to market (Chesbrough & Crowther, 2006). Mechanisms for inside-out processes include, for example, licensing or selling intellectual property (Gassmann & Enkel, 2004). Outbound open innovation can also help the company achieve strategic objectives such as fostering industry standards (Lichtenthaler, 2009). A potential risk of outbound open innovation is that companies weaken their competitive position by transferring too much critical knowledge (Lichtenthaler, 2009). To perform and benefit from outbound open innovation companies need the ability to create the conditions to transfer and convey internal knowledge to external partners (Gassmann & Enkel, 2004; Lichtenthaler & Lichtenthaler, 2009).

Coupled processes: Finally, coupled open innovation processes describe arrangements in which companies combine inbound and outbound open innovation processes. The coupled process is often linked to strategic alliances in which companies absorb external knowledge but also provide internal knowledge to external partners (Gassmann & Enkel, 2004). The extent to which outbound knowledge flow actually constitutes knowledge exploitation in this case is open to debate. Joint marketization as well as joint research and development also classify as coupled processes (Bogers, 2011). Companies require the ability to establish and manage joint development in strategic alliances with external partners in order to benefit from coupled open innovation (Dyer & Singh, 1998; Gassmann & Enkel, 2004). The increasing complexity of managing the interaction with various external partners for different innovation processes may overburden many companies. Possible issues in coupled open innovation relate to intellectual property distribution and appropriation (Paasi et al., 2010), especially when working in "co-opetition" with competitors (Gnyawali & Park, 2011). Furthermore, relying too much on external partners may hollow out internal competencies, leading to a loss of competitiveness over time (Flowers, 2007).

2.3.3 Different external partners for open innovation

Open innovation (inbound) particularly emphasizes the variety of potentially relevant external sources of knowledge and technology. The various types of external partners a company may engage with differ in competencies and areas of expertise (Table 5).[1] External partners therefore differ in the degree to which they provide opportunities for value creation, depending on the particular problems that knowledge and technology companies seeking companies face at a specific point in time. Furthermore, external partners have distinct characteristics that require

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[1] For sake of simplicity the term "external partner" is used for any external knowledge and technology source, although not every interaction with such an external source necessarily denotes a partnership.

attention and present different managerial challenges. The following sections outline the opportunities of working with different types of external partners.[2]

Table 5: Different types of external knowledge sources

Type	Knowledge sources
Market	▪ Suppliers of equipment, materials, components, or software ▪ Clients or customers ▪ Consultants ▪ Commercial laboratories and R&D enterprises
Institutional	▪ Universities or higher education institutes ▪ Government research organizations ▪ Other public sector links ▪ Private research institutes
Specialized	▪ Technical standards ▪ Health and safety standards and regulations ▪ Environmental standards and regulations
Other	▪ Professional conferences ▪ Trade associations ▪ Technical/trade press, computer databases ▪ Fairs/Exhibitions

Adapted from Laursen and Salter (2006)

2.3.3.1 Suppliers as external partners for open innovation

Suppliers are vendors of specific inputs, which they sell to organizational customers. Specific inputs refer to components to be processed as raw materials, sub-components, etc. as well as equipment for processing such as machinery, and software technology.

Opportunities: The innovation and operations management literature documents the important role of technology supplier integration for product and process development (Bozdogan et al., 1998; Carter & Ellram, 1994; Lau et al., 2010; Petersen et al., 2003; Ragatz et al., 2002). Generally, companies can benefit from the experiences and knowledge that suppliers accumulate through their involvement with other customers and industrial lead users (Brusoni et al., 2001; Davies, 2003; Flowers, 2007). In addition to the mere transfer of technology, access to knowledge and experience is the main reason for companies to engage in close interaction with technology suppliers (Petersen et al., 2005; Romijn & Albaladejo, 2002). This offers a number of opportunities for companies to improve their development efforts and operations. The literature presents empirical evidence to demonstrate that interaction with technology suppliers can enable faster market introduction, lower development risks, improved output

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[2] These are the most prominent types of partners that companies can actively interact with. The other types of knowledge sources in the table mainly refer to opportunities for or setting in which interaction can take place, rather thanreferring to types of external partners.

quality, and increased productivity (Pittaway et al., 2004; Ragatz et al., 1997; Ritter & Gemünden, 2003). By working closely with experienced suppliers, companies gain access to technology prototypes as well as external technology expertise. The additional expertise enables companies to detect potential problems earlier in the development process than they could have without the help of suppliers, which in turn means that less engineering change orders become necessary throughout the development of new product or process technologies (Boncarossi & Lipparini, 1994; Lau et al., 2010; Monczka et al., 2000). In addition to development-related contributions, suppliers can engage proactively with the buying companies' decision-making processes by providing information about particular technologies and their application (Athaide et al., 1996; Gerwin, 1988). Likewise suppliers may also contribute towards technology installation, start-up, operations, and maintenance. The supplier's may help to increase installation speed and can provide guidance on operating the new technology (Lager & Frishammar, 2010). Once a process is in operation suppliers increasingly seek to provide further maintenance services to extend their business. For companies this can be an opportunity to tap into the suppliers' expertise for further optimization and technology upgrades (Rönnberg-Sjödin, 2013). With regard to the variety of opportunities for companies to gain advantages from supplier-integration, Wagner and Hoegel (2006) distinguish between "know-how projects" and "capacity projects". Wagner and Hoegel suggest that know-how projects denote a company's motivation to utilize the supplier's specialized knowledge. Capacity projects refer to the exploitation of the supplier's resources to overcome temporary capacity shortages.

Interaction and coordination between companies and technology suppliers regarding technical objectives has positive effects on decision making throughout the development lifecycle (Petersen et al., 2005). Companies have to choose from a variety of possible structural arrangements when working with suppliers (Fliess & Becker, 2006; Monczka et al., 2000; Petersen et al., 2005). With increasing supplier responsibility, these reach from contract development to white, grey, and black box supplier integration (Monczka et al., 2000; Petersen et al., 2005; Wagner & Hoegl, 2006) (Table 6).

Table 6: Different types of supplier integration

Type	Description	Supplier responsibility *Indicates the responsibility of the supplier to make design and build decisions*	Level of integration *Indicates how closely the supplier is involved in the development and implementation work*
Contract development	No supplier involvement; Supplier makes to print	None	None
White-box	Informal supplier integration; Buyer consults with supplier on design specifications	Low	Low-Medium
Grey-box	Joint development activities between buyer and suppliers	Medium	High
Black-box	Design is primarily supplier driven but based on buyer's performance specifications	High	Low-Medium

Adapted from Petersen et al. (2005) and Fliess and Becker (2006)

In contract development the company orders a specific technology and provides the supplier with a clear work order. The supplier produces and delivers the technology according to the company's specification. This arrangement does not actually qualify as supplier collaboration because it does not involve joint development efforts (Fliess & Becker, 2006; Petersen et al., 2005). Companies may also work more closely with suppliers and engage in coordinated development work (Fliess & Becker, 2006). Coordinated development describes arrangements by which companies divide work responsibilities amongst themselves but do not collaborate with each other on these tasks. Nevertheless, the companies share their results and engage in some form of conjoint planning activities to structure their work. Coordinated development is asymmetrical, if the client-company gives clear and detailed instruction to the suppliers (Fliess & Becker, 2006). Such arrangements resemble contract development but involve a higher degree of interaction. The company may seek advice from the supplier regarding specific development issues, but the buying company makes all decisions. This is frequently denoted as "white-box" integration (Petersen et al., 2005). On the other end of the spectrum, the buying company may shift the responsibility for the full development of single modules or more complex technological components of a final product to the supplier (Fliess & Becker, 2006). This is known as "black-box" integration. In these cases, there is not necessarily much interaction between the buying company and the supplier. The company informs the supplier about its expectations and requirements of the new technology, while the responsibility for technology development lies entirely with the supplier (Petersen et al., 2005). Companies may also engage in "grey-box" supplier integration or joint development. This involves regular cooperation between the buying

company and the supplier. Both partners are directly involved in technology development and engage in joint decision making regarding technological specifications (Fliess & Becker, 2006; Petersen et al., 2005).

Challenges: Despite various opportunities and benefits, companies also face several challenges and risks when seeking supplier-integration. While there is substantial evidence for the positive effects of supplier-integration, companies need to be able to manage the interaction with suppliers appropriately in order to realize any benefits. If companies have poorly developed interaction and task coordination abilities, interaction may incur significant costs (Lau et al., 2010; Zirger & Hartley, 1994). In such cases supplier-integration can increase development costs and effort or hamper output quality (von Corswant & Tunälv, 2002; Wagner & Hoegl, 2006). Moreover, companies must be very conscious about the choice of structural arrangements for supplier-integration and matching suppliers with the right tasks. While suppliers may have particular strengths in very specific domains, they often lack a broader knowledge and cannot necessarily be supportive at all stages of the innovation lifecycle (Bessant & Rush, 1995). Successful supplier integration presupposes that the right suppliers are matched with the right tasks (Wagner & Hoegl, 2006). Corroborating this insight, Petersen et al. (2005) find that the conjoint definition of business metrics with technology suppliers can make project teams less effective, which indicates a mismatch between supplier and task, given the supplier's technological rather than managerial expertise. Companies, therefore, face the challenge of identifying supplier capabilities and matching them with adequate tasks.

The literature also suggests that it is a challenge for companies to determine the optimal timing of supplier-integration during the innovation lifecycle. Early supplier-integration has been a particular subject of debate. Some scholars document managers' preferences for the earliest possible integration to build a relationship and mutual understanding with the supplier (Wagner & Hoegl, 2006). However, early supplier integration can be a major issue when companies become "locked-in" after having made specific investments in the wrong technology or partnership. This is particularly dangerous when multiple competing technologies are available (Handfield et al., 1999; Petersen et al., 2005). Likewise, companies can grow dependent on suppliers if they rely too much on the external development capabilities (Flowers, 2007). Companies in the automotive industry, for example, transfer many critical development activities to their suppliers, which increases the amount of value-added by the supplier but also the buyer-supplier interdependence (Oh & Rhee, 2008). In the process industries, Lager and Frishammar (2010) also report a trend towards stronger supplier-integration in post-development stages as suppliers increasingly provide maintenance services, training, and operational management. Outsourcing design, engineering, and operations to suppliers bears the risk of a "loss of negotiation power, leakage of design ideas and loss of engineering

expertise" (Flowers, 2007, p. 321). When companies "hollow-out" their own knowledge base it becomes difficult to remain competitive (Flowers, 2007). Supplier-integration similarly involves the risk that core technology and knowledge may leak to competitors working with the same supplier (Lager & Frishammar, 2010). Determining whether or not to shift development and service responsibilities to suppliers is a critical management challenge. Lager and Frishammar (2010) suggest that the decisions a company makes should be determined by the importance of technological capabilities (e.g. development, implementation, operation, maintenance) and the expected performance improvements of "outsourcing" them to an external partner.

2.3.3.2 Consultants as external partners for open innovation

Consultants are private or organizational change agents that provide companies with knowledge and advice on problem-solving within a specific area of expertise (Bessant & Rush, 1995; Wright et al., 2012). The literature identifies various types of consultants that are relevant to technological innovation, including major league management consultancies, traditional engineering and manufacturing consultancies, human resource management consultancies, and training consultancies.[3] The extant literature on the contributions consultants make to companies' innovation efforts rarely defines the type of consultants under investigation.

Opportunities: Consultants accumulate substantial experience and knowledge through engagements with various clients, across what may be a wide range of industries. This enables consultants to support companies to cope with uncertainty and equivocality throughout the entire innovation lifecycle (Bessant & Rush, 1995; Dawes et al., 1997; Flowers, 2007). Technology development and implementation, for example, requires innovative capabilities such as recognizing technological opportunities or requirements, exploring new technological advancements, or comparing available options, selecting, acquiring, implementing and operating new technologies. If companies do not possess these innovative capabilities internally they may compensate for that lack through collaboration with external consultants (Bessant & Rush, 1995). While temporarily compensating for their clients' lack of capabilities, consultants can enable the company to develop these capabilities internally, by means such as institution building, organizational restructuring and decentralization, or providing training for failure avoidance and better innovation management practices (Bessant & Rush, 1995). Management consultants, as well as engineering and manufacturing consultants, provide an opportunity for clients to tap into significant expertise on administrative and organizational practices. In fact, the contributions these consultants' make often relate "to developing managerial rather than simply technological capability within user firms" (Bessant & Rush, 1995, p. 110). Such capabilities include, for example, analysis and problem definition, support for investment

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[3] Bessant and Rush (1995) also propose that suppliers, universities, or users may be counted as consultants. They are excluded here and discussed as distinct categories later on, to allow for a clearer analytical distinction.

appraisal, decision making, and justification, as well as project management support for implementation (Bessant & Rush, 1995).

In the first instance consultants can help clients diagnose, define and articulate specific issues and needs (Bessant & Rush, 1995). The literature suggests further that consultants cross-fertilize ideas and disseminate technological advancements by transferring knowledge to clients (Hargadon & Sutton, 1997; Reichstein & Salter, 2006). Because of their experience and their knowledge of the industry they can provide access to technology experts and help with the selection of the right expert that a company needs (Bessant & Rush, 1995; Flowers, 2007). However, when considering the suitability of consultants to act as technology brokers, the literature is inconclusive. On the one hand, consultants often have wide ranging access to technology providers and possess central positions in networks of innovating companies (Flowers, 2007; Hargadon & Sutton, 1997). Hargadon and Sutton (1997), for example, show how product development consultants use their position within networks to disseminate existing technological solutions to areas where they are not yet known, thus helping companies to innovate. In contrast, Reichstein and Salter (2006) find that management consultants as sources of knowledge on technological trends have a negative effect on the likeliness that manufacturing companies become process innovators. This finding may result from the company-specific nature of process innovations, which often require adaptation towards the individual context of a company. In contrast, consultants may be more suited to disseminate technological trends that advance product development (Hargadon & Sutton, 1997). In the specific case of process technology adoption, the literature suggests that management consultants will advance organizational change rather than technological change (Hislop, 2002; Swan et al., 1999). This may be particularly important for large companies with limited flexibility that require assistance in managing organizational change (see Appendix 1: Characteristics of large companies). Such companies can use consultants as change agents to promote the implementation of new organizational practices (Wright et al., 2012). In a study on the role of consultants for the support of the introduction of multi-site information systems, Hislop (2002) finds that the level of power and autonomy attributed to consultant significantly affects the patterns of technological and organizational change that occurred in technological (process) innovation projects. More specifically, Hislop reports that companies tend to customize new ERP systems more strongly when they do not work with consultants. In projects where consultants are granted higher levels of power and autonomy there is a stronger focus on organizational changes than on ERP system customization. Similarly, Swan et al. (1999) show that in a direct comparison of similar technology implementation projects between companies in the UK and Sweden, Swedish companies were less likely to work with external consultants and more prone to technological change. In contrast, consultants were more prominent among UK-based

companies, as was the focus on organizational change to adopt the new technology. Consultants also provide temporary capacities for the implementation of unpopular changes (Bessant & Rush, 1995). Whether and to what extent companies are likely to engage consultants to support technology acquisition may also depend on the technology and on the structure of the client company. Companies typically work with consultants if the purchase situation is perceived as novel and complex and therefore creating higher levels of uncertainty (Dawes et al., 1997). However, if a buying center (i.e. decision maker and involved peers) has "good access to external networks, a good degree of usable product class knowledge, and a technical role in the organization" it is less likely that a company will work with external consultants (Dawes et al., 1997, p. 94).

Challenges: The consultancy process requires substantial interaction between client and consultant (Hislop, 2002; Sturdy, 1997). Managing the interaction with consultants, however, is a major challenge for companies. While consultants have in-depth expertise in particular areas, it can be a problem if their expertise is very narrow and does not sufficiently take into consideration the broader effect that the changes they propose may have in specific organizational contexts. Consultants might try to enforce inappropriate solutions that do not fit the client's specific business model (Bessant & Rush, 1995). The dispersion of knowledge across external experts, however, makes it difficult for companies to share internal knowledge with an increasing number of external partners (Hislop, 2002). To circumvent this issue, companies may deliberately seek to invest in long-term relationships with trusted consultants (Hislop, 2002). Conveying internal knowledge is more difficult when companies have to work with consultants that have no prior knowledge of the client company. High workforce turnover in major league management consultancies can, however, impede the creation of a long-term and in-depth consulting relationships (Bessant & Rush, 1995). Moreover, major league management consultancies as well as traditional engineering and manufacturing consultancies can be very expensive. The costs of consulting services may, however, be more problematic for small companies. Large companies are generally more prone to working with consultants, as costs are less important to them than excellent consultation services, in terms of expertise, rapid response, and availability (Bessant & Rush, 1995).

2.3.3.3 Universities as external partners for open innovation

For the purposes of the present thesis universities are simply defined as higher-level educational institutions at which students pursue degrees and where academic research is carried out.

Opportunities: Companies engage with universities for a number of reasons, such as general research, access to scientific expertise, expert networks, or research funding (Perkman et al.,

2011; Perkmann et al., 2013). The interaction between companies and universities includes formal agreements like collaborative research, contract research, and consulting, as well as informal activities like ad-hoc advice and networking (Perkmann et al., 2013). Collaborative engagements with universities are particularly important for large, science-based companies (Fontana et al., 2006; Perkmann & Walsh, 2007; Schartinger et al., 2002). Companies typically consider universities as sources of cutting edge technology discoveries or as partners for knowledge exploration (Perkmann et al., 2013). Universities provide an opportunity for companies to access scientific knowledge and gain insight into emerging technologies (Perkmann et al., 2011). Access to universities' specialized knowledge is more important for companies than accessing inventions that are ready for commercialization (Perkmann & Walsh, 2007). Another reason for companies to seek university collaboration is government funding which increases the companies' overall research funding (Grimaldi & von Tunzelmann, 2002; Perkman et al., 2011). In a similar vein, universities also provide access to a larger network of experts and technologies that companies can access by working with universities (Murray & Stern, 2002; Perkmann et al., 2011).

Challenges: Research on the collaboration between universities and industrial corporations is often approached from the university perspective (Perkmann et al., 2013). Universities collaborate with industrial partners for commercialization and research collaboration (Perkmann et al., 2013). While academic science is driven by curiosity and long-term orientation, the research ambitions of companies typically focus on profit-oriented, short-term outcomes (Perkman et al., 2011). The motivation of universities to disseminate new knowledge publicly is a major issue for private companies. While academic researchers seek publication of research advances in order to build reputation, companies typically aim for secrecy or patent protection to appropriate new technologies (Bogers, 2011; Murray & Stern, 2002; Perkman et al., 2011). Companies may circumvent knowledge dissemination by working with profit-oriented, private research institutes and laboratories rather than universities. Despite their potential differences, existing research predominantly considers universities and research institutes conjointly. The engagement with research institutes may, for example lead to more applicable research output compared to the more basic research conducted by universities. On the other hand, working with research institutes may incur higher costs than working with universities. Contract and industrial research organizations are typically well-equipped and have a particularly high developed, yet narrow expertise in their respective fields of science (Bessant & Rush, 1995).

2.3.3.4 Customers and competitors as external partners for open innovation

Customers (also clients, or users) are organizational or private "actors who expect to profit from an innovation by [acquiring], consuming or using it" (Piller & Walcher, 2006, p. 308). They are

among the most frequently studied external partners in open innovation research on new product development (Piller & Walcher, 2006). Although customers may encourage or demand process innovation, the literature pre-dominantly focuses on customer involvement for product innovation, including process technologies. Likewise, a company may collaborate with direct competitors to advance its innovation efforts. Co-opetition describes the dynamic interplay of collaboration and competition between companies to foster innovation and growth (Gnyawali & Park, 2011).

Opportunities: The main opportunities of customer involvement in inbound open innovation are product development towards customer needs and access to innovative ideas and customer-developed technologies (de Jong & von Hippel, 2009; Lettl et al., 2006). Customer involvement thus goes beyond market research. It creates engagement and provides opportunities to reduce product development risk and lead time, as customers provide additional capacities and pre-developed technologies. The literature identifies different approaches to customer involvement including lead user involvement as well as learning from customers' use of existing products (Enkel et al., 2005), and, more recently, ICT-enabled user toolkits for customer involvement in product design (Dodgson et al., 2006; Enkel et al., 2005; Piller & Walcher, 2006; Prugl & Schreier, 2006). Dodgson et al. (2006), for example, study the case of Proctor and Gamble's "connect and develop" platform for collecting product innovation ideas from customers. Piller and Walcher (2006) examine the case of Adidas-Salomon to explore the use of web-based toolkits to involve customers in ideation and new product development. Similarly, Mount and Garcia (2014) demonstrate how Nestle uses social media to involve customers in new product development initiatives. Customers can also be a trigger for innovation, when users transfer their inventions to producer companies for further development and large scale production, sometimes free of charge (de Jong & von Hippel, 2009). Customers may transfer their internal developments to producers for different reasons of private benefit, such as more suitable final products, feedback and expertise, enhanced reputation, or higher returns on investment than through exclusive, internal appropriation (de Jong & von Hippel, 2009). Lead users in particular may encourage companies to innovate as they experience needs earlier than regular users and are highly motivated to create support the development of innovative solutions, when they expect to benefit from it (Lettl et al., 2006). Customer-initiated innovation has been documented in various industries, such as machine tools, scientific instruments, semiconductors, pipe hanger hardware, pharmaceuticals, or sports equipment, software, and process technology (Hienerth, 2006; de Jong & von Hippel, 2009; Piller & Walcher, 2006).

Enhanced efficiency in development and market introduction is also a major opportunity of working with competitors. Key drivers for co-opetition (i.e. collaboration with competitors) are shorter product lifecycles, technology convergence, and increasing costs of research and

development (Gnyawali & Park, 2011). Companies collaborate with competitors to increase efficiency of new product development and reduce the risk of entering new markets (Hamel et al., 1989). Working with competitors that possess directly relevant capabilities and technologies provides a unique opportunity to enhance and speed up internal innovation efforts and allows companies to reduce research and development expenditure (Zineldin, 2004). As a result, co-opetition can make both companies stronger against outside competition despite reducing the strength differential between the companies (Hamel et al., 1989). Moreover, working closely with competitors enables companies to benchmark each other even if no direct value is exchanged (Gnyawali & Park, 2011).

Challenges: Despite its potential advantages customer involvement also presents companies with various challenges (Enkel et al., 2005). The literature frequently suggests that customer involvement encourages incremental innovation (Bahemia & Squire, 2010; Piller & Walcher, 2006). These positions argue that users are preoccupied with current practices and lack the ability to envision radical change (Hayes & Abernathy, 2007; Lettl et al., 2006). Furthermore, information from customers is often very "sticky"[4], which makes it difficult and expensive to transfer from customers to the company (von Hippel, 1994; Piller & Walcher, 2006). Stickiness can result from the attributes of the information, or the characteristics of the information provider and receiver (Piller & Walcher, 2006). In this regard, companies may encounter severe challenges communicating with customers and reaching a consensus (Enkel et al., 2005). Equally, customers may not be in a position to sufficiently understand new technologies, especially in advanced technological industries (Lettl et al., 2006). This also impedes the acceptance of customer contributions by internal experts (Enkel et al., 2005). These issues incur significant costs that may outweigh the benefits of customer involvement. Close collaboration with customers may also expose a company to increasing dependency (Enkel et al., 2005). Companies can, for example, become dependent on particularly large or otherwise important customers who then demand influence or exclusive access to innovations. Likewise, close collaboration with customers may bias the innovation outcome towards the specific interests or needs of highly engaged customers, even if they only represent a specific market niche. Furthermore, companies face the risk that know-how may leak to competitors if customers have no incentive to remain loyal. These challenges need careful, managerial attention to leverage the potential benefits of customer involvement. In a similar fashion companies face a risk when working with competitors. Co-opetition poses a particular challenge for companies as they directly face the dilemma between knowledge sharing and collaboration on the one hand and opportunistic knowledge exploitation on the other hand (Gnyawali & Park, 2011; Ritala &

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[4] Incurring high incremental expenditure to transfer information in a usable form (von Hippel, 1994). For example the contextually generated knowledge of how a specific product is used and what its limitations are (Rohrbeck et al., 2009).

Hurmelinna-Laukkanen, 2009). At the company level the management of co-opetitive arrangements is therefore mainly concerned with achieving a balance between revealing internal knowledge and maintaining secrecy (Gnyawali & Park, 2011; Hamel et al., 1989).

2.3.4 Openness as a core concept in open innovation

The previous sections showed that there are various opportunities and challenges for companies to be open towards external partners. Systematically managing these opportunities and challenges presupposes an understanding of what it means to be open. Openness has been addressed in different ways, either as a typological construct or as a continuum on which companies can assume different degrees of openness. The following sections introduce these approaches in more detail.

2.3.4.1 Different approaches to classifying openness

In pursuit of classifying different notions of "openness" various authors have proposed frameworks of open innovation categories (Dahlander & Gann, 2010; Huizingh, 2011; Keupp & Gassmann, 2009; Lazzarotti & Manzini, 2009). These classifications map out different modes of open innovation. Huizingh (2011) suggests that different categories of openness result from the combination of open or closed innovation processes and outcomes. Huizingh distinguishes between closed innovation, private open innovation, public innovation, and open source innovation. Dahlander and Gann (2010) classify openness into four categories along the dimensions of innovation processes (inbound vs. outbound) and the monetary nature of knowledge and technology transfer (pecuniary vs. non-pecuniary). Their typology comprises acquiring, selling, sourcing, and revealing as possible manifestations of openness. Lazzarotti and Manzini (2009) argue that openness is a function of the external partner variety (high vs. low) and the number of stages in the innovation lifecycle that external partner are involved in (high vs. low). They distinguish between closed innovators, integrated collaborators, specialized collaborators, and open innovators. Lazarotti et al. (2011) find empirical evidence for all four categories, although open and closed innovators were the most prominent in Italian manufacturing industries. Table 7 provides an overview of the aforementioned classifications.

Table 7: Openness classifications

Openness classifications

Classification 1: Huizingh (2011)

		Innovation outcome	
		Closed	Open
Innovation process	Closed	*Closed innovation*	*Public innovation*
	Open	*Private open innovation*	*Open source innovation*

Classification 2: Dahlander and Gann (2010)

		Direction	
		Inbound innovation	Outbound innovation
Transactions	Pecuniary	*Acquiring*	*Selling*
	Non-pecuniary	*Sourcing*	*Revealing*

Classification 3: Lazzarotti and Manzini (2009)

		Partner variety	
		Low	High
Innovation funnel openness	High	*Integrated collaborators*	*Open innovators*
	Low	*Closed innovators*	*Specialized collaborators*

These classifications are useful frameworks to gain an overview of different openness categories (Huizingh, 2011), discuss their advantages and disadvantages (Dahlander & Gann, 2010), and map out their managerial implications (Lazzarotti & Manzini, 2009). Yet, these frameworks lack a critical reflection of continuous differences in the way companies approach openness, which prevents more nuanced insights on the effectiveness of open innovation. Keupp and Gassmann (2009) provide a further classification, in which they distinguish between isolationists, scouts, explorers, and professionals. In contrast to the previously mentioned studies, however, Keupp and Gassmann derive these categories from empirical evidence rather than from theory. They study openness as a function of the number of a company's external partners and the extent to which the company draws deeply on the external knowledge. Using a Likert-type scale to measure these dimensions, Keupp and Gassman transcend the classification approach and provide a link to another stream of open innovation research which aims to measure rather than to classify openness.

2.3.4.2   Different approaches to measuring openness

A thriving stream of research now focuses on measuring openness and its effects in relation to the open innovation proposition that companies should become more permeable to facilitate inter-organizational flows of knowledge and technology (Bahemia & Squire, 2010; Fontana et al., 2006; Henkel, 2006; Horváth & Enkel, 2014; Inauen & Schenker-Wicki, 2011; Laursen & Salter, 2006; Terjesen & Patel, 2014).

Openness has been defined, conceptualized, and measured in different ways. One approach is to study openness in terms of the activities pursued to increase the permeability for inbound or outbound flows of knowledge and technology (Fontana et al., 2006; Lichtenthaler, 2008). These activities can, for example, be divided into searching, screening, and signaling (Fontana et al., 2006). In this context, search describes a general attitude of seeking knowledge from a variety of external sources. Screening refers to the identification and selection of the most suitable knowledge source. Signaling refers to the voluntary act of disclosing internal information to indicate internal competencies and attract external partners.[5] Other open innovation activities are inter-organizational collaborations, technology acquisition, and R&D contracting-out (Huang & Rice, 2012).[6] Considering outbound open innovation, Lichtenthaler (2008) measures open innovation through various items relating to the planning, intelligence gathering, negotiation, realization, and control of inside-out open innovation processes. A different approach to measuring openness is to focus on the number of external sources that have contributed towards a specific project (Praest Knudsen & Bøtker Mortensen, 2011). Similarly, Huang and Rice (2012) measure the degree of openness as the number of sources that a company draws upon when seeking external knowledge. In a review of the literature on measuring inbound open innovation Bahemia and Squire (2010) show that despite different definitions of openness, search breadth, i.e. the number of external knowledge sources a company draws upon, is actually one of the most prominently investigated dimensions of openness. The intensity of interaction or depth of external search can be equally important to the investigation of openness. Given that the variety of external partners and their relevance to a company's innovation performance matter, the number of external search channels and the extent to which companies draw deeply on them both constitute important measures (Bahemia & Squire, 2010; Horváth & Enkel, 2014; Laursen & Salter, 2006; Terjesen & Patel, 2014). It is now frequently

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[5] Fontana et al. apply the following measurements: Search is number of search channels and the mean of the percentage of new products and processes introduced in collaboration with external partners to indicate the willingness to look for external information. Screening asks if the company engages in the study of scientific journals; and whether it has received government funding for R&D. Signaling asks whether the company puts out patents to signal its own abilities to external partners?

[6] Huang and Rice measure interorganizational collaborations by aggregating six binary values on six forms of collaboration, and technology acquisition as technology buy-in intensity in terms of dividing total expenditures by accumulated tech acquisition expenditure.

stated that investigating both breadth and depth is a fruitful approach to studying openness (Horváth & Enkel, 2014; Terjesen & Patel, 2014).

Search breadth: Search breadth as a central constituent of openness has been addressed in different ways. In deductive studies the breadth dimension typically refers to the scope or number of different search channels. Search channels refer to different types of external sources that companies can access to gather knowledge and technology (Laursen & Salter, 2006, 2014; Terjesen & Patel, 2014). Katila and Ahuja (2002) label search breadth as "scope", which they define as "the degree of new knowledge that is explored" (p.1184). They measure scope with regard to the new patent citations that companies used in a specific year but had not used in the previous five years. Laursen and Salter (2006) define breadth as "the number of external sources or search channels that firms rely upon in their innovative activities" (p.134). They construct breadth as the aggregate result of 16 different sources that companies work with or not. Similarly, Terjesen and Patel (2014) define search breadth as the number of different types of external sources upon which a company draws. They measure breadth by asking companies to indicate whether they have used one or more of a set of "information sources for innovation activities over the last three years" (forthcoming). To account for differences in the importance of external sources when assessing breadth, Leiponen and Helfat (2010) and Laursen and Salter (2014) distinguish between breadth for external knowledge sources that are important or very important and those that have little or no importance. Similar approaches to breadth have been adopted in a variety of studies (Huang & Rice, 2012; Lee et al., 2010; Sofka & Grimpe, 2010). More recently, Laursen and Salter (2014) distinguish between external sources that merely inform a company's innovation activities and those that a company formally collaborates with during the innovation activities [7]

Search depth: Search depth typically refers to the extent to which companies draw deeply on external knowledge. Depth has been operationalized in different ways. One approach is to measure the frequency of interaction between a company and a specific partner (Inauen & Schenker-Wicki, 2011).[8] Katila and Ahuja (2002) define depth as "the degree to which search revisits a firm's prior knowledge" (p.1184). They argue that the more often a company uses the same knowledge, the more in-depth is the company's external search. Katila and Ahuja thus relate depth to the exploitation of existing knowledge. Following this argument, they measure depth by calculating a company's average repetition of citations over the previous five years. Laursen and Salter (2006) define depth as "the extent to which firms draw deeply from the different external sources or search channels" (p.135). They measure depth by calculating the

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[7] The latter are more sustained but may also require more managerial attention

[8] Inauen and Schenker-Wicki focus on six different types of external partners and ask whether or not and how often the companies work with these partners for inbound open innovation (never, rarely, sometimes, often, very often).

sum of sources which respondents indicated to use to a high degree. Such sources that the respondents indicated to not use or only to a low or medium degree were not counted. Subsequently they add up the knowledge sources that a company uses to a high degree. This results in a general value for the degree of depth to which a company draws on external knowledge. Similarly, Terjesen and Patel (2014) suggest that depth relates to "how deeply a firm accesses external knowledge" (forthcoming). They extend Laursen and Salter's (2006) binary approach and measure depth as the indication of an external stakeholder's degree of importance as perceived by the respondents on a scale from one (not at all important) to five (highly important). Other studies have taken similar approaches to those mentioned above (e.g. Sofka & Grimpe, 2010).

2.3.4.3 Empirical research on the effectiveness of openness

Empirical research on the breadth and depth dimensions of openness has produced valuable insights into the effectiveness of open innovation. Studies on search breadth have argued that a broader search could increase the chances of re-combining knowledge from external sources in a way to create valuable innovation (Leiponen & Helfat, 2010). On the other hand, breadth may impede innovation as an increasing number of external knowledge sources incurs greater search costs, while the marginal novelty of knowledge is likely to diminish (Katila & Ahuja, 2002; Leiponen & Helfat, 2010). In fact, Laursen and Salter (2006) present empirical evidence from the manufacturing industries that search breadth is curvilinearly (inverted U-shape) related to product innovation. This finding suggests that increasing breadth is beneficial up to a certain point, after which companies risk "over-searching" by investing too much time, labor, and funding into search (Laursen & Salter, 2006). A similar effect has been documented for the relationship between search depth and product innovation performance (Katila & Ahuja, 2002; Laursen & Salter, 2006). These findings suggest that at some point managerial attention and the organizational resources that increasing depth requires start to impede a company's ability to innovate. Likewise the importance that companies assign to appropriability ("their approach to protecting their knowledge against being copied and to appropriating the returns from their innovative activities") affects search breadth (Laursen & Salter, 2014, p. 867). Initially a strong focus on appropriability will increase breadth because it sends positive signals to collaborators. However, at some point it will start to affect search breadth negatively because collaboration becomes too difficult, for example due to complex internal coordination mechanisms to gain approval for interaction with external partners (Laursen & Salter, 2014). This effect is likely to be more significant for formal collaboration than for informal modes of interaction (Laursen & Salter, 2014).

While the studies discussed above focus on product innovation, Terjesen and Patel (2014) present different results for the case of process innovation. In relation to breadth Terjesen and

Patel argue that companies who divert their resources and attention to a broad range of external sources impede their ability to obtain tacit knowledge and cope with the complexity and systemic impact involved in process innovation. Terjesen and Patel present evidence to support their hypothesis that search breadth is negatively related to process innovation. However, they also demonstrate that industries with high process heterogeneity demand broader search in order for companies to identify potentially relevant knowledge. As far as the depth dimension is concerned, Terjesen and Patel find that, in contrast to product innovation, search depth has a positive linear relationship with process innovation. They argue that deep search involves intense collaboration, possibly repeated interactions, and strong social integration, thus improving a company's ability to absorb external knowledge. Terjesen and Patel then suggest that due to the generally highly tacit and systemic nature of process innovation a greater search depth advances a company's ability to successfully develop and implement new processes. Especially in industries with high productivity growth, deep search is necessary to compete on efficiency and thus seek to draw deeply from external sources to improve their ability to absorb new technologies (Terjesen & Patel, 2014).

The literature on breadth and depth, as outlined above provides valuable insights. Yet, to date the study of breadth and depth has overwhelmingly focused on the strategic company-level, while micro-level perspectives (e.g. project level) remain underresearched. The existing research is largely deductive and studies breadth and depth as separate search strategies. This does not provide any insights into the management and content of search breadth and depth or how companies combine these strategies. In this sense research on the qualitative differences between open innovation practices is equally important (Dahlander & Gann, 2010). The next sections address these issues in more detail.

2.3.4.4   Towards a micro-level perspective on openness

The studies on breadth and depth of open innovation tend to focus on the strategic company-level. They do not show that different operating conditions may require different configurations of breadth and depth (Bahemia & Squire, 2010). A company's various search channels each have their own processes and norms that the company has to address to render search effective within that specific channel (Laursen & Salter, 2006; Terjesen & Patel, 2014; Wagner & Hoegl, 2006). Different projects and lifecycle stages present companies with distinct challenges and opportunities to structure the interaction with external partners. Yet, the deductive studies that have hitherto dominated the literature on search breadth and depth as the main determinants of openness do not provide sufficient insight on the interaction processes that underlie them. The following sections review antecedent literature of understanding the content of openness in more detail.

Governance perspective: The governance literature discusses various forms of structuring inter-organizational interaction, such as mergers and acquisitions, joint ventures, alliances, joint research and development, research contracting, and outsourcing (Bianchi et al., 2011; Chiesa & Manzini, 1998; van de Vrande et al., 2006). Chiesa and Manzini (1998) identify 13 organizational governance modes for technological transfer collaboration. They suggest that governance modes differ with regard to level of integration, impact on the company (existing organizational structures, assets, human resources), time horizon, control, costs, flexibility, and level of formalization. In order to choose an adequate collaboration structure companies must identify a governance mode that matches their requirements in relation to these dimensions. Chiesa and Manzini find that three main factors determine a company's requirements: the purpose that the collaboration serves; the content of collaboration (e.g. technology and market familiarity; relevance to company's core competitive advantage; stage of the innovation project); and the characteristics of the potential partners in terms of culture or bargaining power. The governance perspective emphasizes the importance of the content of interaction with external partners. The type of external partners and the governance modes that companies choose for interaction depend on the purpose of interaction, which in turn differs along the stages of the innovation lifecycle (Bianchi et al., 2011; Chiesa & Manzini, 1998).

The governance perspective on inter-organizational collaboration focuses mainly on strategic decision making but does not reveal how companies actually interact with external partners during an innovation project (Lager & Frishammar, 2010; Rönnberg-Sjödin & Eriksson, 2010). The involvement of external partners, however, is not only a strategic decision but also a managerial challenge at the operational level (Wagner & Hoegl, 2006). Such an operational perspective requires a focus on how managers enact the collaboration with external partners (Bahemia & Squire, 2010). Likewise, the variety of search channels comprise a plethora of motivations, conditions, and backgrounds that require managerial attention (Laursen & Salter, 2006; Terjesen & Patel, 2014). This emphasizes the need for a managerial perspective on open innovation in different projects (Bahemia & Squire, 2010; Horváth & Enkel, 2014) and at different innovation lifecycle stages (Dahlander & Gann, 2010; Lager & Frishammar, 2012). In a recent systematic review on the state of open innovation, however, West and Bogers (2014) conclude that it remains unclear "how" companies integrate and commercialize external technologies. While the deductive literature on open innovation breadth and depth (Katila & Ahuja, 2002; Laursen & Salter, 2006, 2014; Terjesen & Patel, 2014) investigate their effect on a company's innovation performance, they do not show how breadth and depth differ across projects or how companies enact them. The governance literature (Bianchi et al., 2011; Chiesa & Manzini, 1998; van de Vrande et al., 2006) shows that different projects or project stages require different forms of collaboration, but it also falls short of showing how companies interact with

external partners along the innovation lifecycle (Lager & Frishammar, 2010; Rönnberg-Sjödin & Eriksson, 2010). The literature on technology transfer offers a relevant perspective in this respect, as it specifically addresses issues that relate to managing the movement of physical technology and the knowledge to operate it (Lager & Frishammar, 2010; Stock & Tatikonda, 2000).

Technology transfer perspective: Technology transfer can broadly be defined as the "movement of physical equipment, transfer of the necessary skills to operate the equipment, and an understanding of embedded cultural skills" (Lager & Frishammar, 2010, p. 703). Generally, technology transfer can take place at any relational level, for example between companies, professions, industries, sectors, regions, or countries (Lager & Frishammar, 2010). The literature often uses "technology transfer" synonymously with "knowledge transfer", yet the two can be distinguished. Technology transfer denotes the exchange of tangible tools and equipment. Knowledge exchange refers to the transfer of a technology's underlying principles that make it work (Gopalakrishnan & Santoro, 2004). On the other hand, technology is often understood as the application of knowledge (Gibson & Smilor, 1991; Rogers, 2003). From this perspective, technology transfer goes beyond the mere exchange of tools and equipment and also includes the transfer of information to create new knowledge and stimulate new ideas (Gibson & Smilor, 1991). To consolidate these perspectives it may be argued that technology transfer does not necessarily require the transfer of knowledge about the fundamental principles that make a technology work, but nevertheless sufficient relevant information to enable knowledge of the proper utilization of the technology by its recipient. The recipient of new software technology, for example, does not necessarily require knowledge about the code underlying the software, but does require sufficient knowledge to install and utilize it properly. Technology transfer clearly differs from technology diffusion in its deliberate attempt to transfer technology and knowledge (Lager & Frishammar, 2010). In their search for external knowledge companies do not randomly approach different sources but deliberately seek relevant providers of knowledge and technology (Sofka & Grimpe, 2010). Technology transfer puts a focus on the management of the information exchange processes by which companies facilitate the flow of knowledge and technology from provider to recipient (Lager & Frishammar, 2010). It therefore offers a useful perspective for study of managing open innovation.

Technology transfer from source to recipient requires the interaction between both (Gibson & Smilor, 1991; Lager & Frishammar, 2010; Pittaway et al., 2004; Trott et al., 1995; Wagner & Hoegl, 2006). Technology transfer is an inherently interactive process by which different parties exchange technology, knowledge, and ideas until they reach a consensus on understanding the technology and its implications (Gibson & Smilor, 1991). The quality of information sharing, participative decision making, and project commitment determine the performance of a

development project (Gerwin, 2004; Wagner & Hoegl, 2006). Against this background Stock and Tatikonda (2000, 2004) and Tatikonda and Stock (2003) make a key contribution to the operationalization of interaction for technology transfer arguing that technology transfer is an operational problem, whereby companies integrate external technologies through interaction with external partners. According to this view, companies must manage external technology integration projects through systematically structured interaction, in order to achieve effectiveness and efficiency in technology transfer. In this respect Stock and Tatikonda re-emphasize various limitations in the existing literature on inter-organizational interaction. Their main criticism is that most studies focus on the choice of governance modes, discussing collaboration at the "political, corporate or strategic level of analysis rather than an operational project level" and therefore neglect the interactional dimension of technology transfer (Stock & Tatikonda, 2000, p. 720). To address this issue they outline a framework for companies to match levels of inter-organizational interaction (information processing capabilities) with the levels of uncertainty that the technology entails (information processing requirements). More specifically, Stock and Tatikonda argue that from the recipient's perspective, new technologies involve different levels of uncertainty depending on their tacitness, novelty, and complexity. Companies need to match their interaction with the level of perceived uncertainty in order to maximize technology transfer effectiveness in terms of cost, time, and functionality. The level of interaction is a function of the communication, coordination, and cooperation between the companies.[9] These dimensions (communication, coordination, and cooperation) are further explained in the framework chapter of this thesis (see section 3.4). Stock and Tatikonda's model is depicted in Figure 6.
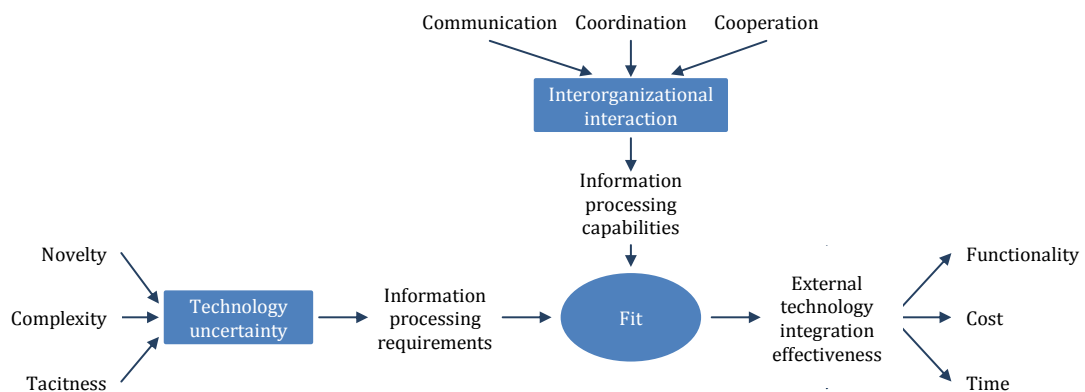
Figure 6: External technology integration (Adopted from Stock and Tatikonda, 2004)

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[9] Communication describes the exchange of information in the joint decision process and refers to the methods of communication, magnitude and frequency of communication, as well as the nature of in- formation exchanged; Coordination describes the structure of inter-unit interactions and decision making and relates to the nature of the planned structure and process of interactions and decision-making between source and recipient; Cooperation is described as the attitude towards the other partner and relates to the willingness of the partners to pursue mutually compatible interests rather than to act opportunistically.

Stock and Tatikonda's model is insightful because it establishes technology transfer as interaction at the operational level. It shows that companies need to adapt the interaction with external partners to different project contingencies along three observable and well-established dimensions (Bahemia & Squire, 2010; Stock & Tatikonda, 2004; Wagner & Hoegl, 2006). A limitation of their model, however, is that it specifically refers to technology uncertainty and its three underlying components (tacitness, novelty, complexity) as the central determinant of companies' information processing requirements, although uncertainty is only a very specific aspect of a technology transfer project. Other factors may equally affect a company's requirements for interaction. Moreover, these may change during the course of an innovation project (Stock & Tatikonda, 2000, 2004; Tatikonda & Stock, 2003).

Openness at the project level: Bahemia and Squire (2010) provide a simple conceptual model of open innovation in which they transfer breadth and depth to the project level. In particular, they suggest that an adequate configuration of breadth and depth at the project level will positively affect new product performance. Like Stock and Tatikonda (2000) they suggest that depth refers to the interaction with external partners, while breadth describes the number of different types of external partners. Only recently has empirical literature started to transfer search breadth and depth from company to project level (Horváth & Enkel, 2014). In a case study of Henkel, Horvarth and Enkel (2014) show that the company adjusted the levels of search breadth, depth, and abstraction to the specific problems in different projects. Horvarth and Enkel's study builds on qualitative data and thus provides insight into the content of breadth and depth. Going beyond the counting of external sources, they discuss breadth with regards to partner variety as well as selection criteria and the industrial distance between Henkel and its external partners. In a similar vein to Stock and Tatikonda (2000), they discuss depth with regards to the intensity of collaboration and information sharing.

The models by Bahemia and Squire (2010) and Horvarth and Enkel (2014) advance open innovation research by transferring breadth and depth to the project level. They further promote the idea that companies combine search breadth and depth to adjust openness to individual project conditions (cf. Katila & Ahuja, 2002). This is particularly important with regard to conditions of limited resources, when drawing deeply from external sources may impede a company's ability to search broadly and vice versa (Horváth & Enkel, 2014; Terjesen & Patel, 2014). Like Stock and Tatikonda (2000) they do not, however, account for differences between project stages. Other literature, however, strongly suggests that lifecycle stages differ in their requirements and conditions for inter-organizational interaction (Fliess & Becker, 2006; Lager & Frishammar, 2012; Petersen et al., 2005; Rönnberg-Sjödin, 2013). Based on a case study in the German window and facades industry, Fliess and Becker (2006), for example, explore the interaction between companies and their suppliers in new product development projects. They

show that concept development, detailed development, process engineering, and product introduction involve different coordination tasks, thus requiring different instruments for interaction. Further studies on open innovation on the lifecycle stage level provide similar insights but relate to open process innovation and are further reviewed in section 2.6 of this thesis.

Summary: The previous sections traced the path from openness classifications to measuring openness along the dimensions of search breadth and depth at the company-level, to approaches that attempt to understand different modes of interaction for open innovation. While governance modes highlight the need for different structural forms to collaboration according to project or lifecycle stage requirements, the technology transfer literature stresses the focus of understanding the content of interaction for the exchange of knowledge and technology. Only recently has open innovation research started to focus on the content of breadth and depth at the project level. The literature further suggests that interaction also differs across individual stages of the innovation lifecycle. These insights suggest that the study of breadth and depth needs to focus on the lifecycle stage as the level of analysis to understand open innovation as a managerial phenomenon at the operational micro-level.

2.3.5 Basic principles of absorptive capacity as a central theme in open innovation

Inbound open innovation suggests that companies can create value from external knowledge and technology. This view presupposes that companies have the ability to recognize and to internalize valuable external knowledge. Against this background, absorptive capacity (AC) (Cohen & Levinthal, 1990) has become a central theme in open innovation research (Dahlander & Gann, 2010). AC is relevant for open innovation research as it provides a conceptual perspective on a company's internalization of new, external knowledge. The academic discourse on AC is broad and oftentimes inconsistent in the definition and application of relevant terminology (Lane et al., 2006). The following sections focus on key studies in this area to introduce the fundamental components of AC.

2.3.5.1 Key dimensions of absorptive capacity

Cohen and Levinthal (1990) were the first to discuss AC. They argue that external knowledge sources are critical for companies' ability to innovate. To create value from external knowledge companies need the ability to "recognize the value of new information, assimilate it, and apply it to commercial ends" (Cohen & Levinthal, 1990, p. 128). Cohen and Levinthal suggest that a company's ability to understand and use new information depends on its relevant prior knowledge (Cohen & Levinthal, 1990; Robertson et al., 2012). From this perspective, companies develop AC as a by-product of internal research and development.

Zahra and George (2002) criticize the lack of clarity on the definition of AC and its operationalization. To address this issue, Zahra and George (2002) redefine AC "as a set of organizational routines and processes by which firms acquire, assimilate, and exploit knowledge to produce a dynamic organizational capability" (p.186). This definition puts a focus on the processes, routines, and practices by which companies absorb external knowledge and make AC more palpable (Lane et al., 2006; Lewin et al., 2011). Zahra and George (2002) further distinguish between potential AC (acquisition and assimilation) and realized AC (transformation and exploitation). Potential AC denotes a company's ability to be receptive towards new knowledge. Realized AC refers to a company's ability to create value from new information. The ratio of realized to potential AC describes a company's AC efficiency, i.e. how good companies are at translating external knowledge into products or processes (cf. Todorova & Durisin, 2007). In this regard, Zahra and George focus on AC for short-term efficiency and exploitation. However, this diverts the focus from the relevance of AC for the broad exploration of external knowledge (Lane et al., 2006).

In an extensive review of the AC literature, Lane et al. (2006) synthesize the three main components from Cohen and Levinthal's (1990) definition with the process perspective advanced by Zahra and George (2002), albeit without a distinction between potential and realized AC. Their definition reads:

> Absorptive capacity is a firm's ability to utilize externally held knowledge through three sequential processes: (1) recognizing and understanding potentially valuable new knowledge outside the firm through exploratory learning, (2) assimilating valuable new knowledge through transformative learning, and (3) using the assimilated knowledge to create new knowledge and commercial outputs through exploitative learning (p. 856).

Based on the aforementioned definitions, the following sections outline the different AC dimensions to establish a basis for further discussion.

Recognizing external knowledge: Recognizing the potential value of external knowledge is a basic component of, and necessary condition for, AC (Cohen & Levinthal, 1990; Lane et al., 2006; Todorova & Durisin, 2007). The ability to recognize external knowledge is sometimes subsumed under a broader exploratory learning dimension, in which companies recognize and understand new knowledge before further transformation occurs (Lane et al., 2006; Lichtenthaler & Lichtenthaler, 2009). This undervalues the importance of recognition as a distinct process that precedes understanding. Todorova and Durision (2007), for example, suggest that rather than understanding external knowledge, recognition is about "…seeing or understanding the potential of the new external knowledge…" (p.777). Recognizing potential is necessary to trigger

further processes to understand and absorb new knowledge (Lewin et al., 2011). Earlier research commonly suggests that the ability to recognize valuable knowledge depends on a company's prior knowledge (Cohen & Levinthal, 1990; Lane & Lubatkin, 1998; Zahra & George, 2002). Zahra and George (2002), for example, propose that "the greater a firm's exposure to diverse and complementary external sources of knowledge, the greater the opportunity is for the firm to develop its [AC]" (p.193).

Assimilation and transformation: According to Zahra and George (2002) assimilation "refers to the firm's routines and processes that allow it to analyze, process, interpret, and understand the information obtained from external sources" (p.189). Knowledge assimilation is also part of Cohen and Levinthal's (1990) original AC paper. In addition, Zahra and George (2002) introduce knowledge transformation as a further AC component. Transformation refers to the "ability of firms to recognize two apparently incongruous sets of information and then combine them to arrive at a new schema" (Zahra & George, 2002, p. 191). From this perspective, transformation occurs as a consequence of assimilating new knowledge that is not initially compatible with prior internal knowledge. In a critique of Zahra and George's AC construct, Todorova and Durisin (2007) suggest that transformation and assimilation are two separate, yet alternative, or potentially alternating processes. According to Todorova and Durisin transformation occurs when new knowledge cannot realistically be altered to fit with existing knowledge structures. In this case "the [existing] cognitive structures of the individuals themselves must be transformed to adapt to an idea" (p.779). When new knowledge fits well with existing cognitive schemas, companies only have to slightly alter new knowledge to adapt and integrate it. In this case, the existing cognitive structures do not change, but new knowledge is "assimilated." Before companies can exploit new knowledge there may be several iterations of assimilation and transformation (Todorova & Durisin, 2007). Patterson and Ambrosini (2015) provide empirical evidence for such a configuration of the AC construct. More specifically, they show that transformation and assimilation interact with acquisition and exploitation rather than unfolding sequentially (cf. Todorova and Durisin, 2007). Lane et al. (2006) subsume transformation under assimilation and thus return to Cohen and Levinthal's (1990) original AC definition. In Lane et al.'s (2006) model, assimilation occurs through transformative learning. They posit that transformative learning "involves several processes that affect how the newly acquired knowledge is combined with the existing knowledge of the firm" (p.858). At the individual level, transformation occurs by relating the new knowledge to what is already known. To absorb external knowledge, however, companies have to diffuse the new knowledge internally (Cohen & Levinthal, 1990). Transformative learning at the organizational level therefore specifically includes knowledge diffusion across the organization (Lane et al., 2006). It is commonly accepted that internal knowledge diffusion requires social integration routines and processes to

communicate and transfer knowledge to a broader range of internal stakeholders (Lane et al., 2006; Lewin et al., 2011; Todorova & Durisin, 2007; Zahra & George, 2002). The nature of knowledge and the associated generative and transformative mechanisms may be of particular relevance in this regard. Nonaka and Takeuchi (1995) suggest that knowledge generation and transfer involves socialization (tacit to tacit knowledge transfer), externalization (explicating tacit knowledge through documentation and conceptualization), combination (organization and accumulation of explicit knowledge), and internalized (explicit to tacit knowledge transfer by diffusion and practice). According to this so called S-E-C-I framework knowledge is continuously generated and transformed among stakeholders as they engage in interaction and learning processes. Internal gatekeepers are particularly important in this regard, as "communication systems may rely on specialized actors to transfer information from the environment … and translate the technical information into a form understandable to the research group" (Cohen & Levinthal, 1990, p. 132). Despite the three different perspectives on the relation between assimilation and transformation, a common thread is the desired outcome of a transformed knowledge base as a result of combining new external knowledge with prior internal knowledge.

Exploitation: Exploitation broadly refers to the application of new knowledge for commercial ends (Cohen & Levinthal, 1990; Lane et al., 2006; Zahra & George, 2002). The commercialization of new external knowledge to achieve organizational objectives is a necessary condition of AC (Cohen & Levinthal, 1990; Zahra & George, 2002). Zahra and George (2002) define exploitation as "an organizational capability that allows firms to refine, extend, and leverage existing competencies or to create new ones by incorporating acquired and transformed knowledge into its operations" (p.190). Similarly, Lane et al. (2006) refer to exploitation as "using the assimilated knowledge to create new knowledge and commercial outputs through exploitative learning" (p.856). In order to enliven the exploitation of new knowledge, companies need the ability to introduce the technology and diffuse new knowledge internally (Zahra & George, 2002). To enable the exploitation of new knowledge, communication with the operators of the new knowledge and technology is imperative. According to Lewin et al. (2011), such capabilities require routines of "sharing knowledge and superior practices across the organization" (p.87), for example by providing information material, organizing workshops, or facilitating cross-functional teams.

2.3.5.2 The underlying constituents of absorptive capacity

Despite the prevalence of AC in the innovation management literature, the "specific organizational routines and processes that constitute AC capabilities remain a black box" (Lewin et al., 2011, p. 81). A particular problem with capacities and their underlying capabilities is that they are not directly observable (Lane et al., 2006; Lewin et al., 2011). Empirical studies typically

hitherto predominantly use proxies such as R&D investment, patents, or co-authored papers to measure AC (Lane et al., 2006).

Zahra and George (2002) advanced AC by redefining it as a bundle of routines and processes, but only recently has research started to put a more explicit focus on the practices and routines underlying absorptive capacity (Comacchio & Bonesso, 2012; Easterby-Smith et al., 2008; Lerch et al., 2012; Lewin et al., 2011; Müller-Seitz, 2012). Such routine-based approaches to the investigation of AC facilitate the discussion of capabilities with regard to observable practices and thus promise to reveal new insights on how knowledge absorption occurs. In order to introduce the routine-based approach to AC research, the following sections first outline the underlying dimensions of AC.

- **Capacities** describe the abstract notion of the extent to which a company can perform certain tasks, such as absorbing new knowledge for example. Capacity results from "groups of capabilities that can be used for a common purpose but may be significantly different from each other" (Robertson et al., 2012, p. 823). A company's capacity for particular tasks thus results from its relevant capabilities that build this capacity (Amit & Shoemaker, 1993; Cohen & Levin, 1989; Teece, 2007). Recall that AC comprises the capabilities to recognize, assimilate, transform, and exploit external knowledge.

- **Capabilities** are bundles or sets "of differentiated skills, complementary assets, and routines that provide the basis for a firm's competitive capacities" (Teece et al., 1997, p. 28). It is generally posited that capabilities result from the coordination, application and exploitation of resources over time and determine what a company can do based on its resources (Amit & Shoemaker, 1993; Grant, 1991). Capabilities are enacted by routines and practices of exploiting, applying, or even altering a company's resources (Teece et al., 1997; Zahra & George, 2002).

- **Resources** refer to all assets available to a company. This comprises physical capital resources, such as hardware and software technology, research and production facilities, or raw materials; human capital resources such as operators, training, experience, networks and relationships, or managerial expertise; and organizational capital resources like reporting structures, and planning or coordination systems (Amit & Shoemaker, 1993; Barney, 1991; Wernerfelt, 1984). Resources may also span company boundaries or be embedded in relationships with external partners (Dyer & Singh, 1998; Lavie, 2006). Given the diversity of these resources it may be highly difficult to manage different resources.

- **Organizational routines** refer to patterns of collective activities, behaviors, and interactions within company. They are effortful accomplishments that can be subject to change and variation (Becker, 2004). Routines include recurrent patterns of action, as well as rules orstandard operating procedures (Becker, 2004). Routines are generally defined as mechanisms by which companies enact and develop capabilities (Grant, 1991; Lewin et al., 2011). Routines create dynamic capabilities if their application allows companies not only to coordinate and apply resources but do so in a way to alter, refine, or extend the existing resource base to address changes in the competitive environment (Eisenhardt & Martin, 2000; Lewin et al., 2011; Teece et al., 1997; Winter, 2003).

- **Meta-routines and practiced routines:** Lewin et al. (2011) propose a distinction between different types of routines to operationalize the AC construct. They distinguish between meta-routines and practiced routines. Meta-routines are "higher-level routines that define the general abstract purpose of routines" (Lewin et al., 2011, p. 85). They are unobservable and in different configurations make up a company's capabilities. They are expressed by practiced routines, such as rules, procedures, norms or habits, programs or managerial practices. Practiced routines are observable, company-specific, and can involve highly tacit knowledge. Nevertheless, they have a common underlying purpose by which they can be collated into meta-routines that can be generalized across companies and describe internal and external AC capabilities (Lewin et al., 2011).

For the purpose of this thesis the relationship between capacities, capabilities, routines, and resources, as outlined in the previous paragraphs is depicted in Figure 7 and can be summarized as follows: Capacities result from groups of capabilities, which in turn result from configurations of meta-routines. Meta-routines are higher-level routines that describe the general purpose of different lower-level practiced routines that relate to the coordination and application of a company's internal and external resources. Capabilities are dynamic if they enable a company to reconfigure and renew the existing resource base.
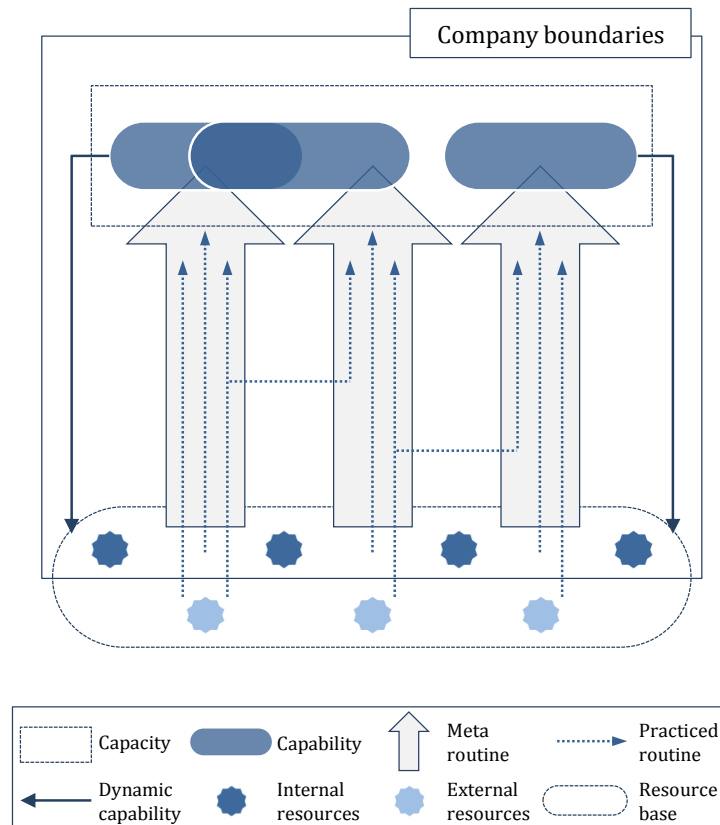
Figure 7: Absorptive capacity model

The routine-based approach to the investigation of AC: Based on the absorptive capacity model as depicted in Figure 7 suggests that by observation of and inquiry about practiced routines, their more abstract, common purpose can be identified, which leads to the identification of different meta-routines. As meta-routines reflect a company's capabilities, the focus on meta-routines provides a bridge between the abstract notion of capabilities and the observable practices by the company ultimately deploys its capabilities. This approach is rooted in the conviction that "direct measurement of capabilities is not necessary if the theory can specify the origins and consequences of capabilities" (Lewin et al., 2011, p. 82). By focusing on observable events of enacting capabilities, the routine-based approach promises to reveal new insights into the black box of AC.

The following example provides a brief illustration of how the routine-based approach works. The capacity to absorb new knowledge is determined by an interaction capability, which in turn reflect such meta-routines as "presenting internal issues", and "documenting conversation results". Such meta-routines may include routines and practices such as meeting, talking, presentations, writing protocols, sending out meeting memos, setting up podcasts or livestreams, etc. Such practices require resources such as location and communication technology as well as knowledgeable employees with the skills to talk to other experts.

Previous applications of the routine-based approach: The strength of the routine-based approach to AC research is that it allows empirical insights into the underlying content and practices of AC capabilities. It facilitates the identification, study, and discussion of routines and their purpose that make up a company's capabilities for knowledge absorption. While Lewin et al. remain conceptual in their approach, Müller-Seitz (2012), Lerch et al. (2012), as well as Patterson and Ambrosini (2015) provide empirical studies. In a study on network level AC in the semiconductor manufacturing industries, Müller-Seitz (2012) studies observable social practices (e.g. "attending workshops", "hosting conferences", etc.), which can be grouped into more general repetitive patterns (e.g. "congregating"). These repetitive patterns resemble Lewin et al.'s (2011) concept of meta-routines and provide a basis for the discussion of the purpose of specific routines to understand how companies deploy AC capabilities and how "new knowledge is actually absorbed" (Müller-Seitz, 2012, p. 92).. Patterson and Ambrosini (2015) particularly study the process of knowledge absorption with reference to key activities and moderating effects of the different AC components, as well as internal and external stakeholders involved in knowledge absorption. Lerch et al. (2012) document and discuss a variety of practices for knowledge absorption in technology transfer between universities and private companies.

2.3.6 Conclusion

This part of the literature review addressed the literature on open innovation. The review included a perspective on open innovation processes, openness, the motivation for interaction, as well as on the construct of absorptive capacity. Moreover, several important research gaps were highlighted. Figure 8 depicts the main insights from this review.

Figure 8: Key insights from open innovation literature

2.4 Lifecycle perspective on innovation as a process

2.4.1 Overview of different lifecycle perspectives

Research from a lifecycle perspective takes an interest in the organizational activities and processes that lead to different innovation outcomes. Lifecycle models help identify typical interdependencies and managerial challenges companies encounter throughout the innovation process (Gopalakrishnan & Damanpour, 1994). The innovation and operations management literature documents various types of lifecycle models and frameworks, which may be described as linear, recursive, chaotic, or complex adaptive systems (McCarthy et al., 2006; Salerno et al., 2015). Rothwell (1994) distinguishes between five generations of lifecycle models at the organizational level. These provide a clear introductory overview of the structure and main focus of different types of models, and include:

- **Linear technology push; market pull:** Technology push describes a sequential process by which internal research and development "push" an innovation to the market. Market pull describes a sequential process, in which the market "pulls" innovation from companies and triggers research and development. Both models prioritize the triggers for innovation, rather than the relevant activities of the innovation lifecycle.

- **Coupling and interactive models:** Coupling and interactive models posit that technology push and market demand are coupled at each stage of the innovation lifecycle. These models emphasize "how" companies create innovation, rather than the initial stimulus for innovation (Galbraith, 1983). They challenge the assumption of linearity and introduce feedback loops to the distinct yet interacting stages of the innovation lifecycle (Kline & Rosenberg, 1986).

- **Functional integration models:** Functional integration models conceptualize the innovation lifecycle as a set of integrated, simultaneous, or concurrent organizational activities. Central work activities, such as research and development, product development, production engineering, or parts manufacture run simultaneously or overlap to a great extent to exploit synergies between different experts and eliminate waste.

- **Integrated and networking models:** These models focus on effectiveness, efficiency, flexibility, and speed. They describe innovation as a set of concurrent activities and processes, which involve real-time information processing, and rely on advanced information technology for communication, simulation, modelling, virtual reality, data mining, and rapid prototyping (Dodgson et al., 2006). In addition, these models point towards the importance of external collaboration. They put an explicit focus on the flow of knowledge and technology across organizational boundaries at different stage of the innovation lifecycle (Chesbrough, 2003; Trott, 2008).

2.4.2   The stage-gate model as an analytical tool

The stage-gate model developed by Cooper (1990) is one of the most prominent innovation lifecycle frameworks. The stage-gate model depicts innovation as a sequence of four to seven stages that comprise clearly defined objectives and activities. Between the stages "gates" act as checkpoints for progress evaluation and project plan refinement. Depending on the evaluation outcome, companies can proceed to the next stage, terminate the project, or repeat the previous stage (Figure 9).
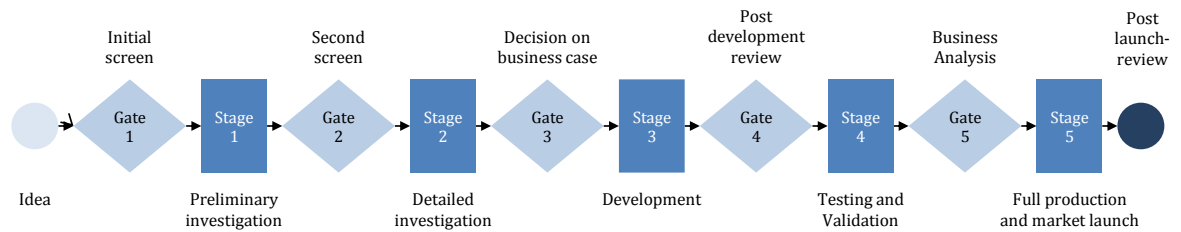
Figure 9: Stage-gate process model (Adapted from Cooper, 1990)

One of the most common criticisms of the stage-gate model is its linear depiction. It has been suggested that it does not realistically describe the innovation process. This is true because any innovation process is likely highly complex and company-specific. However, the strength of the stage-gate model lies precisely in the way it provides a theoretical framework for investigating the innovation process from an analytical perspective (King, 1992). It provides a comprehensible structure for a complex and challenging organizational phenomenon (McCarthy et al., 2006). It identifies relevant activities and provides a tool for the effective and efficient planning and management of development work (Cooper, 1990). Despite its linear depiction, the model advocates that iterations, loops, and sequential activities occur within and across stages (Cooper, 2008). By establishing critical activities, it provides an opportunity to assess the potential for parallel or concurrent work order (McCarthy et al., 2006). In fact, the linear representation, which was originally advanced by Utterback (1971), is common to most lifecycle models in the innovation management literature (Salerno et al., 2015). While the stage-gate model remains conceptual, its structure and immense popularity among scholars and practitioners make it a strong advocate for the application of linear models in the analytical study of development lifecycles. This provides substantial opportunities for research on open innovation throughout the innovation lifecycle.

The classic stage-gate model focuses on guidelines for new product development. It does not outline activities and objectives for other development projects, such as technology development (Cooper, 2007). The original stage-gate process applies to well-defined and predictable product development projects. Technology development, however, involves more uncertainty and risk. Moreover, it is less predictable, solutions cannot necessarily be envisioned, and prospects are unclear at the beginning of a project (Cooper, 2007). Cooper therefore suggests that technology development would require a dedicated lifecycle model. More recently, Salerno et al. (2015) question which innovation processes fit best with different types of projects. They adopt a contingency-theoretical perspective and show that different types of innovation projects require different processes, which can differ in structure and in content. Any work attempting to identifying patterns in the innovation process needs to take into account the context and the attributes of the innovation (Gopalakrishnan & Damanpour, 1994). While the

generic, linear stage-gate logic may be applicable to different development projects and forms of innovation for analytical reasons, lifecycle models nevertheless need to take into account the contingent characteristics of the specific innovation form that they addressed (Cooper, 2008; Salerno et al., 2015; Tidd et al., 2005). Against this backdrop, the following sections provide an overview of the literature on the process innovation lifecycle.

2.4.3   The process innovation lifecycle

Despite the importance of process innovation for organizational competitiveness, relatively little is known about the development and implementation of new processes (Frishammar et al., 2012; Hayes et al., 2005; Lager, 2011). Managing new process development and implementation has received far less attention in the literature than product development (Frishammar et al., 2013). Yet, process development is equally "enabled through planned, structured, and formalized work processes" (Frishammar et al., 2012, p. 8). The importance of distinguishing between different forms of innovation has been established (Tidd et al., 2005). Yet, early studies on the process innovation lifecycle often do not distinguish between product and process innovation or apply the same principles to both (cf. Hayes et al., 2005; Utterback, 1971). Other authors treat process innovation as a sub-component of product development and highlight the complementarities between both (Clark & Wheelwright, 1993; Hayes et al., 2005; Wheelwright & Clark, 1994). Clark and Wheelwright (1993), for example, describe how companies create new products and associated production processes through iterations of design-build-test cycles, in which products and processes are conceptualized and tested until a final design is achieved. Similarly, Hayes et al. (2005) discuss process innovation as an enabler of competitive advantage complement to product development efforts. Nevertheless, the existing literature identifies different stages of the process innovation lifecycle as well as relevant activities and objectives in these stages (Clark & Wheelwright, 1993; Gerwin, 1988; e.g. Kurkkio et al., 2011; Voss, 1992).

Identification of different lifecycle stages: In a pioneering contribution to the study of innovation processes, Utterback (1971) describes a three-stage innovation lifecycle in which companies recognize the need and opportunity for innovation (idea generation), develop technological solutions (problem-solving), and apply them as new production processes within the company (implementation and diffusion). Utterback remarks that innovation includes the application of a new technology and that this distinguishes product from process innovation. Application refers to market introduction in the case of product innovation, and the first use in production for process innovation. Pisano (1994) and Lager (2000) present two frequently referenced accounts of major lifecycle stages in the processing industries. Pisano (1994) distinguishes between process research, pilot development, and commercial plant start-up. Lager (2000) distinguishes between idea generation, process development, and implementation.

Lager (2000) argues that process development differs from product development in terms of its triggers and locus of application. Product development is often considered to start with an assessment of market opportunities and end with the commercialization of new products on the market. In contrast, process development starts with the identification of production needs and ends with the transfer of new processes into production (Lager, 2000).

While the models above account for the major stages in a conceptual process innovation lifecycle, further studies have provided more detailed conceptualizations of the different lifecycle stages. Lager (2011), for example, distinguishes between four stages and eight sub-stages, thus offering a more detailed insight into the process innovation lifecycle. In the specific context of processing industries, Lager shows that following initial exploration, large-scale process and facility development is carried out with a continuously increasing level of detail. The development team then gradually hands the process over to the operators, before further improvement occurs during process operation. Lager points out that process innovation differs from other forms of innovation by its drivers and objectives. In the context of discrete manufacturing processes, O'Hara et al. (1993) describe a five stage process innovation lifecycle, which includes initiation (exploring need for product or process requirements), concept and path definition (identification, evaluation, and selection alternative and planning the path to technical solution), concept validation (establishing feasibility of concept and final design concept), refinement and verification (set up of new technology and introduction of new operations), and production and support (full scale production and on-going improvements). O'Hara et al. particularly highlight the role of technological and organizational change, as well as the management of systemic integration as distinguishing process innovation characteristics that companies must address during the innovation lifecycle.

Front-end lifecycle stages: Several authors have highlighted the importance of front-end activities in process development. Jensen and Westcott (1992) emphasize project selection and justification in particular, as well as concept development and the choice of adequate process technology in line with the company's manufacturing strategy. Specifically, they argue that companies should gradually refine different process innovation candidates through multiple iterative loops of concept development and ultimately select the candidate that emerges as the most closely aligned with the company's manufacturing strategy. For this purpose, Jensen and Westcott outline tools and methods that companies can apply to select adequate technology. They explicitly highlight the importance of assessing new technology but also of considering the people affected by process innovation. Similarly, Frishammar et al. (2013) focus on process definition during the front-end of the innovation lifecycle. They identify ten dimensions of process definition, which relate to the strategic assessment of process innovation, the conceptual exploration of solutions, an assessment of the risks involved in the process concepts,

and an outline of project and implementation plans. Frishammar et al. explicitly point towards issues of system integration, when they highlight the importance of clearly identifying organizational interdependencies which could be affected by a new process. Kurkkio et al. (2011) echo the importance of front-end activities in a study of the "fuzzy" front-end of process innovation. The "fuzzy" front-end denotes "the initial phase of the innovation process [which] precedes the typical formal stage-gate approach" (Kurkkio et al., 2011, p. 490). It begins with the idea for a change and ends with the decision about whether or not to launch a formal development project. Kurkkio et al. identify that the "fuzzy" front-end comprises informal start-up, formal idea-study, formal pre-study and formal pre-project. They argue that the front-end is of particular importance because it is a key determinant for development work at later stages of the innovation lifecycle. The studies above agree that high levels of uncertainty and equivocality are particular challenges during the front-end of process innovation (Frishammar et al., 2011, 2013).

Back-end lifecycle stages: The back-end of the innovation lifecycle is also important to successful process innovation as it relates to the implementation of new processes (Voss, 1992). Voss describes process innovation success as the realization of technical success and the realization of business objectives. He defines implementation as "the process that leads to the successful adoption of an innovation of new technology" (Voss, 1992, p. 31). Following this assertion Voss postulates a lifecycle model that comprises the evaluation of process innovation solutions, the installation and commissioning of new technology which ends when a process is operation, and a consolidation stage for further improvements. Voss argues that successful implementation does not automatically result from sophisticated technology but rather from an effective management of process implementation. This involves purchase and installation, but also strategic and technical planning, as well as operator consultation. Focusing solely on the acquisition of new technology without consideration of organizational change is a major reason for not achieving the full benefits expected from the technology. Therefore, Voss emphasizes, that organizational change but also complexity and systemic impact involved in process innovation require specific managerial attention throughout the innovation lifecycle.

Intermediary lifecycle stages: The detailed development of new processes is necessary between the front and back-end of the innovation lifecycle (Tyre & Hauptman, 1992). Tyre and Hauptmann argue that during the implementation of technological process innovation companies often face difficulty of dealing with technical complexity, systemic shift, and project size, which they can omit to some extent by engaging in preparatory activities prior to process implementation. Gerwin's (1988) study on the development and implementation of computer-aided-manufacturing processes is a key contribution in this respect. Gerwin suggests four generic stages of the innovation lifecycle, including adoption, preparation, implementation, and

routinization. Gerwin outlines the relationships between strategic and operational mechanisms of dealing with technological, financial, and social uncertainty at the different stages. In this context, the preparation stage is shown to be of particular importance in order to modify new, externally acquired technologies for implementation within the existing organization, but also to plan for organization change to accommodate the new technology.

2.4.4 Conclusion

The review in the previous sections shows that the process innovation lifecycle comprises various activities and challenges. For analytical purposes these can be depicted as a linear sequence. In particular the review showed that the lifecycle needs to consider front-end activities, back-end activities, as well as an intermediate preparation stage. The review also shows that existing studies indicate the importance of characteristics, such as technological and organizational change or systemic impact in individual stages. Yet, existing studies do not systematically trace these components throughout the innovation lifecycle. Figure 10 depicts the main insights from the review of the literature on the innovation lifecycle.
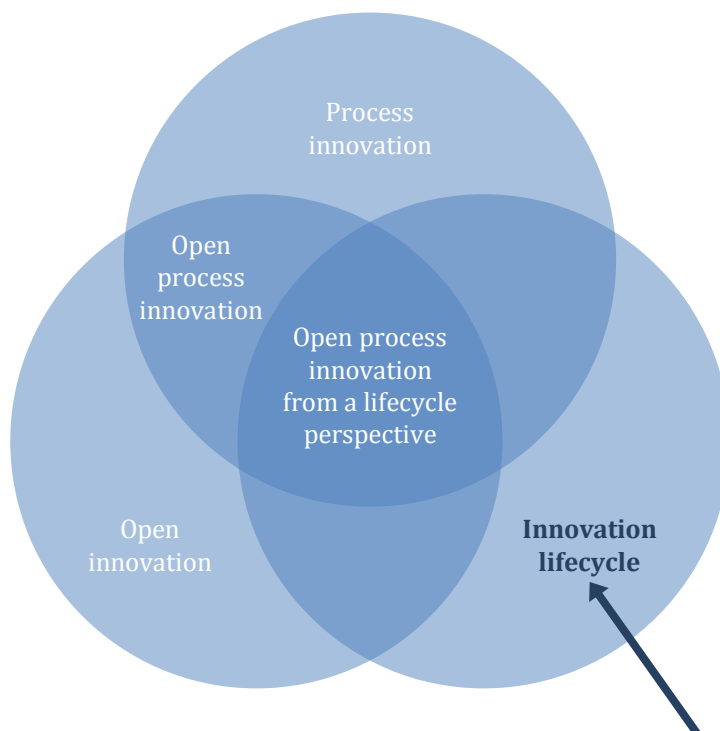
Process innovation

Open process innovation

Open process innovation from a lifecycle perspective

Open innovation

Innovation lifecycle

(Process) Innovation lifecycle:
- Comprises various managerial activities and challenges along front-end, back-end, and intermediate preparation stages
- Can be depicted as a linear sequence for analytical purposes
- Needs to account for context and innovation attributes to determine conditions that shape patterns of coping with managerial activities and challenges along different stages

Figure 10: Key insights from innovation lifecycle literature

2.5 Open process innovation

In the context of increasing interest in open innovation, West and Gallagher (2006) have wondered and suggested that future research should explore whether "open innovation [is] as powerful a framework for process as it is for product innovative activity?" (p.329). However, concerns have been raised that the potential input of external partners for process innovation beyond technology supply is inherently limited because "compared to product innovations, knowledge about hard and soft organizational issues is much more important and the details of processes are also much less visible to outsiders" (Huizingh, 2011, p. 5). On the other hand, a systematic review of organizational process innovation capability, Frishammar et al. (2012) identified collaboration with external partners as a key antecedent of the ability to realize process innovation successfully. In this context the role of secrecy for knowledge protection and the characteristics of process-related knowledge may affect the structure of interaction between companies and their external partners (Gopalakrishnan et al., 1999; James et al., 2013). Furthermore, it has been suggested that specific capabilities are necessary to complement absorptive capabilities in the context of open process innovation (Robertson et al., 2012). Against this background, the following part of the literature review focuses on open process innovation to identify key insights as well as determinants of this phenomenon. Open process innovation is defined here as collaboration between a company and its external partners for the development and implementation of new internal processes. The sections to follow exclude the literature on open process innovation from a lifecycle perspective, which is reviewed separately (see section 2.6).[10]

2.5.1 Key issues in previous open process innovation literature

In an early contribution, Utterback (1971) argues that the technical and economic environment provides companies with critical information for technological (product and process) innovation. Utterback (1971) expects that:

> ...the major boundary transfer during problem solving would occur between the firm
> and outside sources of technical information. This would probably involve an active
> and structured search on the part of individuals within the firm (p.79).

Technology suppliers as a source of technology are usually recognized as the most important external partners in this context. In this regard, the literature on interaction between process technology buyers and suppliers is a precursor to open process innovation research. Reichstein

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[10] This is deemed necessary to first identify the contingencies of open process innovation and then compare how the literature that directly relates to the core of the present thesis accounts for these contingencies.

and Salter (2006) for example argue that "it is often necessary for firms to work closely with suppliers to understand and utilize the full potential of the new technology" (p.659) when implementing new equipment (knowledge flow from manufacturer to user). Many such antecedent contributions to open process innovation focus on the potential areas of contribution by technology suppliers as reviewed in section2.3.3.1. Nevertheless, other external partners, such as competing and non-competing companies, customers, and consultants, have been suggested as important potential collaborators for process innovation activity (Linton, 2000; Reichstein & Salter, 2006; Terjesen & Patel, 2014). Earlier research indicates that external partners could potentially assume different roles at different stages of the innovation lifecycle (e.g. Lager, 2011). This is furthered outlined in the following sections.

2.5.1.1 Antecedent literature and contributions by process technology suppliers

Technology suppliers provide information on potential technological solutions and help reduce uncertainty during the early stages of an innovation project. During the later stages, suppliers can help companies develop the appropriate infrastructure for new technology, for example by providing training and supporting technology installation (Gerwin, 1988). Athaide et al., (1996) adopt the perspective of technology suppliers to map out key areas of interaction with buyers of process technology. They find that suppliers do not only deliver technologies but seek active involvement with their customers to enhance the commercialization of their own products. Athaide et al. identify eight basic dimensions along which process technology suppliers seek interaction the buyers of their technologies, including: product customization, gathering feedback on process technology performance, provision of education and training, ongoing support for upgrades and maintenance, proactive involvement in decision making, process technology demonstrations, ad-hoc support for troubleshooting, and clarifying the product's relative advantage. Based on an extensive literature review Meyers et al. (1999) also propose a direct positive link between buyer-seller communication and innovation success. In particular, they suggest that collaborative technology development and intense knowledge exchange between buyers and suppliers will enhance the success of initial process technology implementation. Possible forms of collaboration between process technology buyers and suppliers include technology development and customization, strategic alliances to leverage access to novel technologies and integrated information systems, training and education arrangements, vertical integration, and knowledge transfer to enhance initial process technology adoption among operators. Tyre and Hauptmann (1992) highlight the importance of knowledge transfer during the initial start-up of new process technology. They show that ongoing involvement with external technology suppliers and experts leads to more successful process implementation in terms of start-up time and operating improvement. However, when engaging with external experts, companies need to be aware of challenges such as divergent

objectives and expectations (Tyre & Hauptman, 1992) or the suppliers' limited experiences with novel or particularly complex technology (Gerwin, 1988).

2.5.1.2 Recent key studies on open process innovation

The existing literature also outlines further potential areas for external contributions to process development and implementation. Generally, a variety of external sources of knowledge and technology may contribute to a company's process innovation efforts (Frishammar et al., 2012; Reichstein & Salter, 2006). Yet, only recently, research has started to investigate the relevance of different external knowledge sources for open process innovation. Reichstein and Salter (2006) make a key contribution to this debate. Based on a sample of 2885 UK manufacturing companies[11], Reichstein and Salter investigate internal and external sources of radical and incremental process innovation (technological and organizational). In particular, they refer to suppliers, customers, consultants, and universities, as well as to standards and regulations as the main sources of external knowledge for process innovation. They find that companies typically adopt narrower search strategies for process innovation than for product innovation. In particular, technology suppliers are the most important external sources for process innovation. Reichstein and Salter argue that suppliers introduce new technology into the economic system and therefore give impetus to a company's ability to adopt process innovation. In contrast, they find that drawing on knowledge from consultants and customers decreases the likelihood that companies will introduce process innovations. Reichstein and Salter explicitly point out that these findings are counterintuitive and may result from unobserved company characteristics.

Huang and Rice (2012) recognize the gap in open process innovation and explore the role of openness for the development and implementation of new (technological and managerial) processes. Based on a cross-industrial survey of 4322 Australian companies, they find that inter-organizational collaborations and technology acquisition as basic approaches to open innovation have a significant positive effect on the introduction of process innovation. Nevertheless, they document a concave (inverted U-shape) relationship between breadth and process innovation and conclude that searching too broadly has negative effects on the adoption of new processes.

In a recent study Terjesen and Patel (2014) investigate how search breadth and depth affect the companies' successful adoption of process innovation and how the industrial environment moderates the effect of these search strategies. In contrast to Huang and Rice (2012), they provide evidence that search breadth has a linear and negative, rather than a concave, relationship with process innovation. Terjesen and Patel (2014) argue that limited AC prohibits companies from absorbing previously unknown and unrelated knowledge from a wide range of external sources. Terjesen and Patel argue that the costs and attention required to search

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[11] CIS UK innovation survey; reflecting the national demographics in terms of company size distribution

through a variety of channels that involve different processes, routines, norms, and roles prevents companies from understanding external knowledge. Nevertheless, they find that companies operating in industries with high levels of process heterogeneity (the extent to which companies within an industry have different input-output conversion processes) need to deploy broader search strategies to identify potentially suitable solutions to their problems. Regarding search depth, Terjesen and Patel find support for a positive linear relationship with process innovation success. They argue that deep search involves intense and repeated interaction with external knowledge sources, which enhances companies' ability to understand external sources and to acquire, assimilate, and apply new knowledge. Terjesen and Patel further find that industry productivity growth positively moderates the relationship between search depth and process innovation success. They argue that under conditions of high productivity growth companies compete on efficiency. Deep search enhances companies' AC which allows them to understand and implement new technologies more quickly, thus excelling at efficiency.

2.5.1.3 Important limitations of existing work

The studies summarized above make several important contributions. With regard to the insights from the other parts of the literature review in this thesis, however, they remain limited in several respects. The following sections outline these limitations.

Different roles of external partners: Gerwin (1988), Athaide et al., (1996), and Meyers et al. (1999) exclusively refer to technology suppliers and do not consider any other types of external partners for process innovation. Tyre and Hauptmann (1992) indicate that there may be different types of technology suppliers who can support process implementation. They measure the interaction with external partners as "the involvement of personnel from other facilities or organizations during installation and optimization of the new processes [and] the existence of a problem solving partnership with outside experts (5-point scales)" (Tyre & Hauptman, 1992, p. 309). This operationalization does not, however, allow for any insight into the role of different external partners. The studies by Reichstein and Salter (2006), Huang and Rice (2012), and Terjesen and Patel (2014) acknowledge that there are various potentially relevant external partners. Huang and Rice (2012) and Terjesen and Patel (2014) simply measure search breadth as the sum of different types of external partners with whom a company works. This does not provide any insights on the importance of different partners. While Reichstein and Salter (2006) provide important insights into the sources of process innovation, they measure the importance of external knowledge sources at the company level (none, low, medium, high). However, this does not provide any qualitative insights into the content of a company's motivation to interact with specific knowledge sources and how they structure the interaction.

Discussion of the interaction between companies and external partners: The previous studies identify potential areas in which technology suppliers can contribute towards process innovation (Athaide et al., 1996; Gerwin, 1988; Meyers et al., 1999; Tyre & Hauptman, 1992). Yet, they remain limited in several respects. Athaide et al. (1996), for example, provide anecdotal evidence on the suppliers' motivation to work with client companies. They do not, however, show how process innovating companies manage the interaction with their suppliers. While some earlier studies highlight specific risks and challenges of supplier integration, such as suppliers' limited knowledge, dependence on external partners, conflicting interests, or lack of established relationships (Gerwin, 1988; Tyre & Hauptman, 1992), they fall short of discussing managerial responses to these challenges. Similarly, Huang and Rice (2012) study different aspects of open innovation, such as degree of openness, technology acquisition, investments in AC, and R&D contracting-out, but do not show how companies interact in the different collaborations or at different points in time. With a focus on the depth of interaction Terjesen and Patel (2014) measure the indication of an external stakeholder's degree of importance as perceived by the respondents (1 = not at all important to 5 = highly important). Although they posit that deep search involves close collaboration, they do not explain content of depth, i.e. what it means to interact closely and how to manage close interaction (cf. Horváth & Enkel, 2014).

While the literature outlined above demonstrates the importance of external partners for process innovation, it does not provide much insight on how companies manage and structure the interaction across organizational boundaries. Relatively few studies have addressed this limitation (some of these studies relate to open process innovation from a lifecycle perspective and are reviewed in section 2.6). In this respect Stock and Tatikonda's (2004) model for successful external process technology integration is a valuable contribution (see section 2.3.4.4 for model description). They specifically propose a fit between the structure of inter-organizational interaction and technological uncertainty to achieve innovation success. By doing so, they explicitly address the importance of structuring interaction along important dimensions such as communication, cooperation, and coordination. Nevertheless, their work also remains limited because they only focus on external contributions towards technological change and do not discuss the role of different types of external partners. Furthermore, they focus exclusively on technology implementation stage, leaving it for further research to explore critical relational characteristics and processes that occur before external technology implementation (Stock & Tatikonda, 2004).

Different process innovation lifecycle stages: The studies discussed above outline the potential activities and responsibilities of technology suppliers. However, they do not discuss how companies actually involve suppliers along different stages of the innovation lifecycle.

While Athaide et al. (1996) argue that suppliers can contribute to every stage of the innovation lifecycle, they do not map the interaction between technology buyers and suppliers across different lifecycle stages. Gerwin (1988) outlines which tasks companies may assign to technology suppliers in two different lifecycle stages, yet this remains a conceptual contribution and is awarded little attention compared to Gerwin's primary focus on companies' internal activities. Tyre and Hauptmann (1992) specifically refer to the start-up stage but do not consider interaction with external partners prior to installation. Equally, Reichstein and Salter (2006), Huang and Rice (2012), and Terjesen and Patel (2014) use company-level data to investigate open process innovation, which excludes the possibility of different search approaches depending on project contingencies (cf. Bahemia & Squire, 2010; Horváth & Enkel, 2014).

Summary: In summary, the studies above do not address the challenges companies face when managing collaboration with external partners and absorbing new knowledge across different lifecycle stages. They focus predominantly on technology related contributions from external partners but do not discuss the role of other external partners or contributions to other components of process innovation (mutual adaptation, organizational change, or systemic impact). Against this background it still remains a valid claim that:

> …further research is also needed to investigate the specific problem solving processes associated with different characteristics of technological change …. To further extend these ideas to technological process change, future research could examine the form and content of communication flows, and the way subtasks related to the introduction are designed, divided, and coordinated (Tyre & Hauptman, 1992, p. 315).

2.5.2 Determinants of open process innovation

The existing studies on open process innovation provide insights into the effectiveness of external contributions to process innovation (Reichstein & Salter, 2006; Terjesen & Patel, 2014). Further studies shed some light on the potential forms of contributions towards process innovation, especially from technology suppliers (Athaide et al., 1996; Meyers et al., 1999). Yet, the studies only present very few insights into "how" companies manage knowledge and technology transfer in open process innovation (Stock & Tatikonda, 2004). Technology transfer is inherently interactive in nature (Gibson & Smilor, 1991; Lager & Frishammar, 2010; Trott et al., 1995). The structure and content of interaction depends on the characteristics of the knowledge and technology that companies exchange (Bogers, 2011; Stock & Tatikonda, 2004) as well as the willingness and ability to reveal internal knowledge (Mohr & Spekman, 1994). The following sections therefore introduce secrecy and process innovation knowledge characteristics as determinants that potentially affect the content and structure of inter-

organizational interaction in the context of open process innovation. Furthermore, an extension of the AC construct for open process innovation is introduced.

2.5.2.1   Secrecy as a means of appropriation

Innovating companies aim to capture value from their innovation efforts and therefore often seek to impose barriers to imitation. Typical protection mechanisms include patents, secrecy, lead time, and investment in complementary assets (Harabi, 1995; James et al., 2013). The choice of protection mechanisms depends on factors such as the innovation's characteristics, the efficacy of legal protection mechanisms within the given industrial and institutional conditions in which a company operates, and the company's organizational characteristics (James et al., 2013; Teece, 1986). The innovation management literature predominantly finds that secrecy is the most adequate mechanism to appropriate the returns from process innovation (James et al., 2013; Milesi et al., 2013).[12] Companies in discrete manufacturing industries typically commercialize processes internally. As a result, process innovation is less visible and more difficult to reverse-engineer for outsiders than other forms of innovation, such as new products. Moreover, patent application requires companies to disclose their processes to a great level of detail, thus enabling competitors to "invent around" the specifications covered by the patent. At the same time, it is relatively difficult for the innovating company to observe and verify process patent infringement due to the lack of insight into other companies' processes (Bloodgood & Bauerschmidt, 2002; James et al., 2013; Milesi et al., 2013; Teece, 1986).

The importance of secrecy as a means for appropriating[13] process innovation is well documented in the empirical literature. Levin et al. (1987) find a strong tendency across various companies and industries to consider secrecy relatively more important for process than for product innovation, whereas patents are much less effective for process. Likewise, Harabi (1995) conducts a survey of 127 different manufacturing companies in Switzerland and finds that secrecy is relatively more important for process than for product innovation. Cohen et al. (2000) conduct a further study on the role of patents in protecting the gains from innovation. Based on a survey of 1478 US manufacturing companies they identify various problems with patents as protection mechanisms and find that secrecy is clearly the most effective mechanism for process innovation. They comment on their findings that "process innovations are less subject to public scrutiny and thus can be kept secret more readily [and] patent infringements are more difficult to detect for process than product innovation given that the former are less public" (Cohen et al., 2000, p. 10).

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[12] Except for certain industries, such as pharmaceuticals, where products are often distinguished based on the process by which they are created, and therefore patented.
[13] Capturing the returns on investment in innovation

Secrecy can have different meanings. It can refer to legal protection mechanisms between companies and their external partners, such as non-disclosure agreements, strictures on publication, non-compete clauses in employment contracts, etc. (Cohen et al., 2000; Paasi et al., 2010). It can, however, also describe "internal policies and procedures that restrict the flow of information both within and outside the organization" (James et al., 2013, p. 1132). Against this backdrop, Slowinski et al. (2006) distinguish between legal methods and non-legal methods for "ensuring that employees in both firms understand what information must be shared with the partner, may be shared with partner, and must never be shared with the partner" (p.30). A strong focus on legal methods may attract valuable collaborators by "signaling"[14] the possession of valuable knowledge and awareness of knowledge protection. On the other hand, too strong a focus on legal mechanisms can impede collaboration by "signaling" difficult interactions and increasing the costs of internal information processing (e.g. having to obtain clearance for every interaction with external partner) (Laursen & Salter, 2014). As Slowinski et al. (2006) point out, legal methods to ensure secrecy (in particular non-disclosure-agreements) are necessary but not sufficient to protect against unintentional knowledge diffusion. The interaction between companies also depends on the people involved in the interaction at the operational level (Lager & Frishammar, 2010; Slowinski et al., 2006; Stock & Tatikonda, 2000). During the collaboration between companies "what information gets traded is determined day to day, often by engineers and operating managers" (Hamel et al., 1989, p. 134). The ability to share and protect knowledge at the operational level, i.e. during the interaction with external partners, is critical for open process innovation.

2.5.2.2 Process innovation knowledge characteristics

The ability to share and protect knowledge also depends on the focal innovation's knowledge characteristics (Bogers, 2011). According to Gopalakrishnan et al. (1999) and Gopalakrishnan and Bierly (2001) the knowledge required for process development and implementation is to a large extent tacit, systemic, and complex. Process innovations tend to involve relatively high degrees of tacit knowledge because they often build on experiences that have shaped over time, rather than designed to describe a product as required by a customer. As a result, it can be difficult to convey knowledge to external partners that lack these experiences. To convey tacit knowledge close and active participation is necessary, which can hinder collaboration with external partners for process innovation (Gopalakrishnan & Bierly, 2001). Furthermore, the knowledge required for process innovation is often organizationally systemic. This results from the integration of processes with the overall organizational system. It may be difficult to collaborate with external partners if systemic knowledge is required for a particular innovation.

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[14] Voluntary disclosure of knowledge or selective revealing of information in order to solve issues of asymmetric information (Laursen & Salter, 2014)

First of all it can be difficult to coordinate work distribution with external partners for systemic innovation (Chesbrough & Teece, 2002). Furthermore, systemic knowledge can make it necessary to share more information with the external partner than originally intended. As a result interaction may be impeded by a company's fear of exposing itself to its partner's opportunistic behavior (Das & Teng, 1998; Gopalakrishnan et al., 1999; Gopalakrishnan & Bierly, 2001). Finally, process innovation often involves relatively high degrees of complex or architectural knowledge. As with systemic knowledge, complex knowledge results from the inter-relationships between various components and sub-systems in an innovation. In contrast to systemic knowledge, Goaplakrishnan and Bierly (2001) refer to the complexity of the innovative technology itself rather than the organizational system in which it is integrated. Higher degrees of complexity make it more difficult to source innovation externally because it is difficult to explain the required technology to external partners but equally difficult to understand the technology obtained from those partners (Gopalakrishnan & Bierly, 2001). A common thread to these knowledge characteristics is that they provide some degree of protection but also make it more difficult to involve external partners (Hurmelinna et al., 2007). This suggests that coping with these knowledge characteristics in process innovation may require companies to provide external partners with access and substantial internal knowledge. On the other hand companies need to protect their internal skills and knowledge from their partners to prevent knowledge leakage as a result of unintentionally sharing too much information (Hamel et al., 1989). While knowledge sharing can lead to positive effects on innovation performance, unintentional knowledge leaking by operators significantly negatively moderates this relationship, especially in the case of business-critical knowledge "such as trade secrets, core technologies, and other types of strategically important knowledge" (Ritala et al., 2015, p. 23). This creates a general tension of knowledge sharing and protection in collaborative innovation processes (cf. Bogers, 2011), which requires careful managerial attention directed to knowledge exchange during the interaction with different external partners. Lager and Frishammar (2010), thus aptly state that:

> …successful collaboration depends on adequate management of information flows and sharing of knowledge among stakeholders… The important issue is thus to improve such desired information exchange in different kinds of collaborative settings [but also to] understand how undesired information sharing or information leakage can be avoided (p.702).

2.5.2.3 Absorptive capacity for open process innovation

AC is important for open innovation as it determines a company's ability to search broadly and deeply for new process related knowledge (Huang & Rice, 2012; Terjesen & Patel, 2014). Robertson et al. (2012) argue that the AC literature is biased towards learning and knowledge

management, while knowledge application remains relatively neglected. This is a particular issue for open process innovation, where the application of new, externally sourced knowledge and technology are subject to constraints imposed by existing equipment and processes. Robertson et al. suggest that companies have to be very conscious about developing new processes and changing existing ones because even incremental changes and minor modifications can unbalance an entire process setting. It is therefore necessary to understand the capabilities that enable companies to perform open process innovation. Against this backdrop, Robertson et al. specifically discuss capabilities that relate to the application of new knowledge and technology. They advance three capabilities for accessing, adapting, and integrating process knowledge and technology. Similar to absorptive capacity, "accessive capacity comprises all knowledge generating and gathering activities, both internal and external" (Robertson et al., 2012, p. 827). To create value, however, companies also require adaptive and integrative capacity. These refer to capabilities for knowledge application and changing new technology, existing technological infrastructure, and organization. In particular, adaptive capacity involves the capabilities to make changes to new technology to fit with a specific purpose within the company. Integrative capacity involves capabilities to integrate new technologies and processes with the organizational system, and may also involve organizational changes (Robertson et al., 2012).

2.5.3   Conclusion

The review of the literature on open process innovation shows that the technology transfer perspective emphasizes the relevance of interaction structure for the success of open process innovation. Against this background the literature review documents several specific determinants that may affect the structure of interaction with external partners during the development and implementation of new processes. These determinants mainly relate to secrecy as a means of appropriation and the characteristics of process related knowledge. Furthermore, it was shown that previous literature suggests an extension of the AC construct to understand how companies carry out open process innovation. However, key contributions in the domain of open process innovation focus on technological change, while other process innovation components remain largely unaddressed. The existing studies do not show how companies manage open process innovation across the innovation lifecycle in terms of structuring the interaction with external partners (Figure 11).

Open process innovation:
- Has mainly been studied with focus on technology suppliers
- Requires adequate interaction structures for successful technology transfer
- Is shaped by specific determinants such as secrecy as well as sharing and protecting organizational insight
- Requires deployment of specific capabilities for external technology adaptation and integration
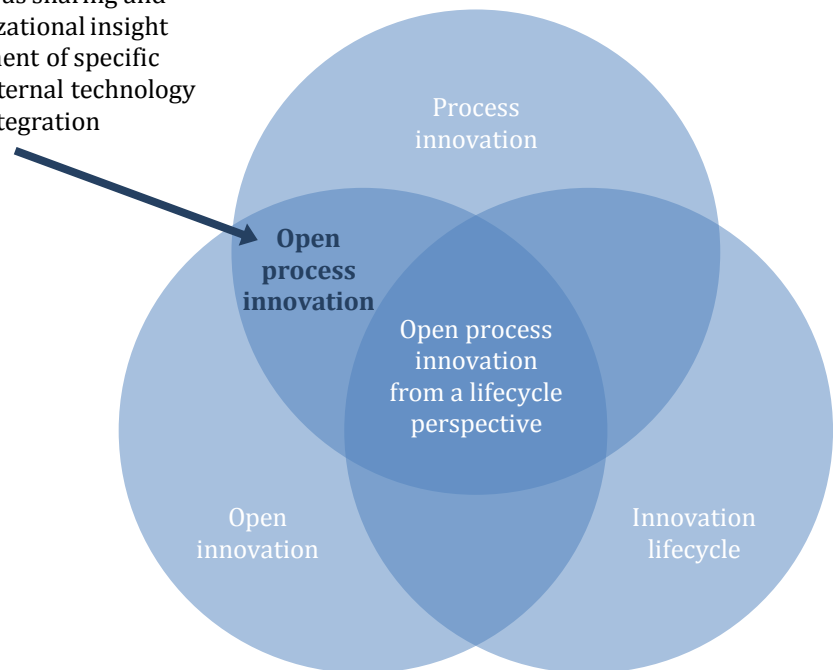
Figure 11: Key insights from open process innovation literature

2.6 Open process innovation from a lifecycle perspective

This part of the literature review introduces and summarizes key studies on open process innovation from a lifecycle perspective, i.e. studies investigating how companies interact with external partners to develop and implement new processes across the different stages of the innovation lifecycle. The purpose thereof is to map out the key findings of previous studies and contrast them with the key insights from the previous parts of the literature review in order to pinpoint the gaps that this thesis addresses. The studies are summarized individually to provide more detail on their contributions and limitations.

2.6.1 Lager and Frishammar: Collaborative development of new process technology/equipment in the process industries

Lager and Frishammar (2012) provide a study on the collaboration between process technology buyers and suppliers during the development of process technology and equipment. More specifically they ask the question: why, when, and how companies should collaborate with equipment manufacturers for innovation? They suggest that the benefits of collaboration include lower development risks and access to the supplier's knowledge base. However, "core

technology" may leak to competitors and coordination may be expensive, disrupt existing operations or cause dependence on the supplier. Regarding the potential for collaboration along the different lifecycle stages, Lager and Frishammar distinguish between three distinct phases of process technology development. The *fuzzy front-end* includes ideation, pre-studies, and functional prototype development. During this stage companies may collaborate with equipment suppliers to screen and evaluate ideas, articulate internal needs, and translate and conduct early concept development. The second stage refers to process technology *development,* and comprises prototype development, testing, and evaluation. During this stage, several iterations of product development have to be passed, either at the supplier's location or within the company. While it may have benefits to develop technology at the suppliers' site in order not to disrupt existing operations, there is often a need to test technology in a real operating environment to assess potential implementation issues. Suppliers are particularly keen to learn from their clients during this stage. The *manufacturing* stage includes the final design and production of one-off equipment. During this stage companies make the final investment decision. The main supplier is responsible for the production of the new technology, which can then be installed at the buyer's site for further development. Each stage involves different levels of commitment from technology buyers and suppliers. Furthermore, Lager and Frishammar suggest that the form of collaboration should be chosen depending on technology newness on the market and on the buying company's perception of the technology's complexity. Technology newness can be low (off-the shelf technologies that are well known and available from many suppliers); medium (existing but incrementally improved technologies); or high (radically new process technology). Similarly, technology complexity can be low (performing one operation); medium (process system, performing multiple operations); or high (a "super-system" of processes like a full production facility). Based on these dimensions they posit appropriate forms of collaboration (Figure 12).
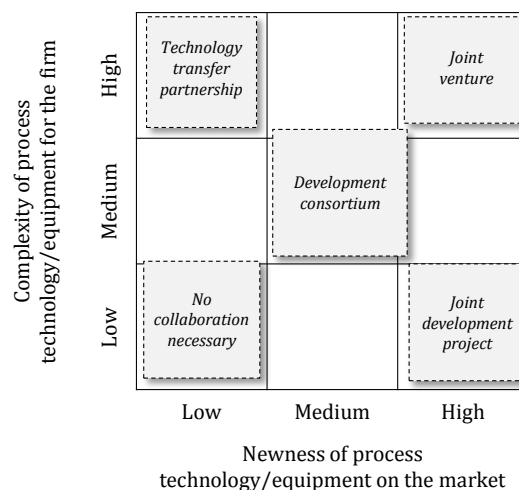
Figure 12: Collaboration matrix I (Adapted from Lager and Frishammar, 2012)

Contributions and limitations: It is important that Lager and Frishammar suggest that collaboration for process development depends on the lifecycle stage contingencies (cf. Lager & Frishammar, 2012, p. 79). Nevertheless, their article only examines the interaction with suppliers and remains conceptual in nature. Although it distinguishes different types of technology (newness/complexity), it does not really discuss these issues nor does it discuss the different forms of collaborations in different settings. In addition, the paper does not refer to different process innovation components. It does not point out how the companies should distribute work responsibilities, how they can deal with knowledge protection and knowledge sharing, how they absorb external knowledge, or what capabilities they need to enable collaboration with external partners. Lager and Frishammar consequently suggest that further research is required to investigate the timing and structure of collaboration throughout the innovation lifecycle while accounting for project contingencies.

2.6.2 Lager and Frishammar: Equipment supplier/user collaboration in the process industries

Lager and Frishammar (2010) study the collaboration between equipment buyers and suppliers for technology transfer during the back-end of the innovation lifecycle (purchasing, start-up, and initial operations). Lager and Frishammar suggest that technology transfer requires mutual interaction between buyer and suppliers. The aim of their study is to provide a basic framework for companies to select adequate forms of collaboration with technology suppliers. Their study specifically focuses on collaboration intensity and the degree of commitment from buyers and suppliers. In this context they provide a conceptual discussion of why, when, and how companies collaborate with suppliers during purchasing, start-up, and operation of new process equipment. During the *purchasing* phase, the relationship with the supplier and technical purchasing details have to be established because they will affect the extent to which the companies work collaboratively towards joint goals. During *start-up* the technology is fully transferred. This is a period of extreme learning for both parties and both parties have a strong interest in collaborating closely to learn from each other. During *operation* there is a further incentive for both companies to learn from each other. The buying company needs to understand how to operate a new technology. If the technology is new to the supplier then the supplier has a particularly large incentive to gather experiences and learn from the initial operations by the client company. As far as the issue of coping with potential unintended knowledge leakage is concerned, they suggest that the structure of collaboration should be decided depending on the importance of a particular technology[15], and on the performance

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[15] They distinguish between contextual (necessary but not value adding; use multiple sources to in-source the capability); critical (important but not core to overall business); and core (vital; use in-house R&D or select only strategic partners).

improvement of new technology expected as a result of collaboration. Lager and Frishammar suggest different opportunities for collaboration as depicted in Figure 13.
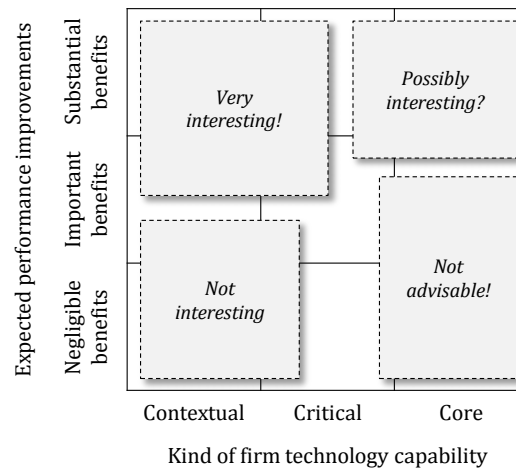
Figure 13: Collaboration matrix II (Adapted from Lager and Frishammar, 2010)

Contributions and limitations: The paper by Lager and Frishammar (2010) is valuable because it highlights the potential for collaboration in different critical stages of process innovation. Furthermore, it points towards potential differences in the structure of interaction depending on the technology's relative importance and expected benefits from collaboration. It also considers the importance of knowledge sharing and protection during open process innovation. Nevertheless, the paper remains limited in various respects. Firstly, it remains suggestive and does not build on empirical data. While the study applies a lifecycle perspective and indicates that the motives for collaboration change along the lifecycle stages, it does not show how companies adapt the structure of interaction. The collaboration matrix is only applied to the project but not the lifecycle stage level. This leaves a gap with regards to "how" companies interact with external suppliers at different stages of the innovation lifecycle. Moreover, the paper only considers technology suppliers as external partners and focuses on external contributions towards technological change. It does not address other components of process innovation. While it shows that learning from partners is important, it remains unaddressed how companies absorb new knowledge.

2.6.3 Rönnberg-Sjödin and Eriksson: Procurements procedures for supplier integration and open innovation in mature industries

Rönnberg-Sjödin and Eriksson (2010) study open process innovation from a lifecycle perspective with specific regard to the interaction between equipment buyers and suppliers. They ask "how process firms can organize and manage supplier integration and open innovation practices when developing and installing new process equipment" (p.656). They argue that

process technology development and implementation typically require close interaction between buyers and suppliers to develop solutions that address the specific needs of the processing company that buys new technology. They suggest a five-stage process technology lifecycle, including concept design, development, installation, start-up, and operation. The work in these stages can be performed by the supplier, by the buyer, or by both working collaboratively. Rönnberg-Sjödin and Eriksson argue that companies adapt their interaction with technology suppliers throughout the different lifecycle stages. More specifically, they suggest that companies can structure the interaction with a technology supplier along several dimensions, including: work distribution, partner selection, contract formalization, payment, subcontractor selection, collaborative tools, and performance evaluation. They use an exploratory case study of two companies in the metals and minerals industry to elicit patterns of interactions throughout the innovation lifecycle. Rönnberg-Sjödin and Eriksson find that companies in their study generally seek early interaction. Nevertheless, their findings also show that the distribution of work performance changes along the entire lifecycle. During *concept design* the process company performs the work largely internally, although the supplier sometimes provide consultancy. During *development* the suppliers perform the main work. While the process-company typically suggests some inputs, suppliers may fear a loss of critical internal knowledge when working too closely with their clients. During *installation* the main work is done by the supplier, again with input from the processing company. It may be the case that both companies collaborate intensively, while the processing company remains responsible for project coordination. Especially in large, complex projects collaboration tends to be intense. During *start-up* the processing company and the supplier engage in frequent interaction to facilitate mutual knowledge transfer and learning. During *operation* the processing company operates the equipment. The companies in Rönnberg-Sjödin and Eriksson's study were typically reluctant to share further insights with external partners at this stage in order to avoid critical knowledge spill-overs. With particular focus on the procurement procedures Rönnberg-Sjödin and Eriksson find that companies employ the same approaches during development, installation, and start-up. The companies use different approaches during concept design and operation when work is largely performed internally. Corroborating earlier studies on process innovation, Rönnberg-Sjödin and Eriksson report that the companies typically do not use patents to protect their processes but instead prefer secrecy. On the other hand, they argue that internal information is often highly idiosyncratic to a company and therefore not relevant for competitors. Against this background they indicate that companies require a good understanding of what can and cannot be shared in order to facilitate successful interaction with external partners.

Contributions and limitations: Rönnberg-Sjödin and Eriksson's study shows that different lifecycle stages offer different opportunities for external contributions. By pointing towards different procurement decisions they show that deliberate managerial decision making is necessary to structure the interaction with external partners throughout the innovation lifecycle. The study lacks a comprehensive perspective on the effect that external contributions may have on process innovation, as it only discusses the interaction with technology suppliers in the context of technological change. Although the paper suggests that knowledge protection is a key theme in open process innovation, it does not distinguish between different technologies and does therefore not account for contingencies in different types of projects (for example, core process technology vs. enabling process technology). While Rönnberg-Sjödin and Eriksson show that careful management decisions are necessary during collaboration, they do not discuss the relevant capabilities that are necessary to absorb new knowledge and how companies deploy them.

2.6.4 Rönnberg-Sjödin et al.: Open innovation in process industries: a lifecycle perspective on development of process equipment

Rönnberg-Sjödin et al. (2011) adopt a full lifecycle perspective to understand the collaboration between equipment buyers and suppliers in open process innovation in more detail. The purpose of their study is to "explore the problems and opportunities faced by process firms and their equipment suppliers throughout the lifecycle stages of collaborative development projects" (p.226). They argue that different stages of the innovation lifecycle involve different problems and opportunities and therefore need to involve different interaction routines. They suggest five stages of the innovation lifecycle, including "fuzzy" front-end, process and product development assembly and installation, start-up, and operation (cf. Lager & Frishammar, 2010). Based on a case study of two companies they identify the opportunities and problems for collaboration at each stage. During the *"fuzzy" front-end* the collaboration intensity is not very high (how this is measured is not described). At this stage it is important to move from vague descriptions to more explicit goals and objectives. During *process development* the supplier needs to understand how a new technology fits within the production system of the buying company. The collaboration intensity is gradually increased during this stage. Mutual information exchange is necessary to finalize the design of a new process technology. It is also important to involve operators but this may be difficult due to a lack of interest. During *assembly* and *installation* the interaction becomes less intense because of the large number of actors involved. It is easier for operators to understand the pending change, which leads to more suggestions for change. Often these additional changes cannot be implemented anymore. During *start-up* the intensity of interaction is considered to be high because it is important to get it right. The supplier is very much involved with the installation of new technology, support implementation, and the

provision of training to operators. During *operation* the intensity of interaction is low in order to protect internal knowledge. Rönnberg-Sjödin et al. (2011) argue that core capabilities should be developed internally and only shared with caution (cf. Chesbrough & Schwartz, 2007). They conclude that the content and intensity of interaction should be tailored to the different lifecycle stages and that this may involve different degrees of openness.

Contributions and limitations: The important contribution by Rönnberg-Sjödin et al. (2011) is that the innovation lifecycle offers different opportunities for collaboration at the different stages. Nevertheless, the paper leaves various gaps with regard to the insights from earlier parts of the literature review. Despite some references towards changing internal organization they only focus on technological aspects of process innovation and ignore other process innovation components. The results remain highly descriptive and the constructs are not well defined (e.g. intensity and openness are mentioned but remain undefined). Furthermore, Rönnberg-Sjödin et al. refer to the importance of knowledge protection but do not engage in further discussion of the subject matter. They argue, for example, that processes are core capabilities that need to be protected, yet they do not explain why it is not a problem to work with companies during the development and start-up of such technology. They also do not refer to the capabilities that are necessary to facilitate the absorption of the suppliers' knowledge, in spite of the fact this is specifically relevant for open innovation.

2.6.5 Rönnberg-Sjödin: A lifecycle perspective on buyer-supplier collaboration in process development projects

Rönnberg-Sjödin (2013) provides another important study from the perspective on open process innovation, albeit from the technology supplier's perspective. Rönnberg-Sjödin documents the interaction between equipment buyers and suppliers across five stages of the innovation lifecycle, including pre-study, purchasing and development, assembly and installation, start-up, and production. Rönnberg-Sjödin adopts the perspective of the supplier to understand the opportunities and challenges they face during the innovation lifecycle. Rönnberg-Sjödin argues that process companies typically lack the resources and capabilities to develop new technology internally. As a result, they often collaborate with technology suppliers to develop technology that meets idiosyncratic requirements. He suggests that collaboration between technology buyers and suppliers is necessary throughout the innovation lifecycle to facilitate technology transfer. According to Rönnberg-Sjödin, typical collaborative activities include joint technology selection, design and development of process equipment, mobilization of joint resources for smooth installation and start-up and possibly operations improvement. His empirical study is based on eight equipment suppliers in the metals and minerals industry. In Rönnberg-Sjödin's study, *pre-study* involves the definition of requirements for process

technology to reduce uncertainty and equivocality. Technology suppliers present proven technologies to their customers and can also act as consultants to help reduce uncertainty and equivocality. *Purchasing* and *development* includes detailed technology and possibly early interaction with end-users. According to Rönnberg-Sjödin the main challenge is coordinating design and acquisition specifications. Non-disclosure agreements may be used to decrease the risk of knowledge leakage. *Assembly* and *installation* comprises the physical implementation of the new equipment in the manufacturing facilities. Rönnberg-Sjödin finds that suppliers aid installation but that it is often a challenge to coordinate collaboration among numerous actors of the partnering companies. *Start-up* includes the initial testing as well as knowledge transfer and training to end-users. Start-up can be very complex due to variety of simultaneous activities, which may impede current operations. The supplier can help provide training and education to the operators of the new technology. Finally, o*peration* includes the operation, upgrading, and fine-tuning of the equipment. During this stage the equipment supplier may provide service and new ideas for optimization on a regular basis.

Contributions and limitations: Rönnberg-Sjödin (2013) contributes to the literature on open process innovation by substantiating the claim that different opportunities exist for collaboration throughout the innovation lifecycle but that these may bring managerial challenges. In this respect Rönnberg-Sjödin also highlights the relevance of interaction between buyers and suppliers in terms of work distribution and coordination. He highlights the issue of knowledge protection, albeit from the supplier's perspective, which technically refers to protecting product- rather than process-related knowledge. Nevertheless, the results remain highly descriptive. Although Rönnberg-Sjödin points towards issues such as the provision of training, he does not present findings that create transparent insights on external contributions towards different process innovation components other than technological change. Because the study adopts the supplier's perspective it does not discuss search breadth, interaction with external partners, or capabilities for managing knowledge absorption from a buying company's perspective.

2.6.6 Conclusion

The review in the previous sections shows that earlier studies on open process innovation from a lifecycle perspective suggest that the motivation for interaction may change across the innovation lifecycle. Furthermore, the work responsibility distributions may change. This is important because it clearly shows the need for research on process development and implementation from a lifecycle perspective. Yet, the existing literature remains limited in various ways, when compared to the key insight from the different streams of literature that it builds upon. The studies do not distinguish between different types of partners and only

consider technology suppliers. Common to all the studies discussed above is the fact that they largely ignore process innovation components other than technological change. Furthermore, they do not define constructs like "openness" or "intensity", and often remain unsystematic with regards to the structure of interaction (an exception are Rönnberg-Sjödin and Eriksson, whose study investigates several dimensions of interaction for procurement). While there are some references to different types of technologies, their impact on the structure of interaction between companies is not further discussed. Likewise, the studies largely refrain from a discussion of open process innovation determinants such as knowledge sharing and protecting or the deployment of relevant capabilities (Figure 14).

Process innovation:
- Is driven by internal operations improvement objectives; comprises low outside visibility; can occur independently or conjointly with other forms of innovation
- Requires top-management support and bottom-up acceptance and is positively affected by presence of technical specialists and influential champions
- May be difficult to coordinate within large, complex organizations
- Involves technological and organizational change for mutual adaptation of new technology and existing organization
- Requires planning and coping with impact on broader organizational system

Previous research on open process innovation from a lifecycle perspective:
- Shows that motivation for interaction changes across stages
- Focuses on technology suppliers and technological change

Research gaps:
- Role of other external partners and contributions to other process innovation components
- Openness construct on lifecycle stage level in context of process innovation
- Relevance of open process innovation determinants
- Deployment of absorptive capabilities throughout innovation lifecycle
- Differences between development of core and non-core processes

Open process innovation:
- Has mainly been studied with focus on technology suppliers
- Requires adequate interaction structures for successful technology transfer
- Is shaped by specific determinants such as secrecy as well as sharing and protecting organizational insight
- Requires deployment of specific capabilities for external technology adaptation and integration

Open innovation:
- May involve inbound, outbound, and coupled processes
- Emphasizes relevance of different types of external partners and managing the interaction with them
- May involve different degrees of openness in terms of search breadth and depth; openness predominantly studied on aggregate firm-level; lacking perspective on operational level
- Requires deployment of absorptive capabilities

(Process) Innovation lifecycle:
- Comprises various managerial activities and challenges along front-end, back-end, and intermediate preparation stages
- Can be depicted as a linear sequence for analytical purposes
- Needs to account for context and innovation attributes to determine contingencies that shape patterns of coping with managerial activities and challenges along different stages

Open process innovation from a lifecycle perspective

Figure 14: Literature review summary and knowledge gaps

2.7   Summary of literature review and research gap

The literature review began with basic principles of innovation research. The literature on process innovation was then reviewed along several dimensions to identify the underlying components of process innovation. These included a focus on internal commercialization, mutual adaptation, technology change, organizational change, and systemic impact. The review of open innovation literature then identified open innovation processes, different types of external partners, and various approaches to measuring openness, as well as capacities for open innovation. It was then shown that the process innovation lifecycle comprises various activities and stages. Against this background, the review engaged with key studies on open process innovation and open process innovation from a lifecycle perspective. Regarding open process innovation the review identified typical knowledge characteristics and appropriation mechanisms for open process innovation. It was shown that the open process innovation literature points towards different external partners but does not further discuss any differences between them. While some studies refer to AC (e.g. Huang & Rice, 2012; Terjesen & Patel, 2014), no study investigates the role of capability deployment in collaboration to facilitate interaction and absorb new knowledge. The lack of literature addressing the content of knowledge and technology flows and the nature of breadth and depth in open process innovation leaves a critical gap, although Stock and Tatikonda's (2004) study on technology transfer clearly points out the importance of studying the qualitative content of interaction more closely. The literature review then showed that the literature on open process innovation from a lifecycle perspective does address collaboration at different stages but falls short in various others respects. As a result of these gaps the theory on open process innovation remains nascent. As the phenomenon essentially draws on different streams of literature that inform theory and practice, research has to incorporate key insights from the different domains that are relevant to open process innovation. Previous literature falls short in doing so. This thesis, therefore, seeks to address the existing gaps and explore open process innovation from an innovation lifecycle perspective with specific regard to process innovation components, motivation for interaction, openness in terms of search breadth and depth at the project-stage level, and the deployment of relevant capabilities. The next chapter provides an outline of the conceptual framework guiding the study's empirical approach.

3 Conceptual research framework

The framework maps out relevant constructs and defines categories for the exploration of open process innovation from a lifecycle perspective. The constructs result from relevant insights identified in the literature review. The framework defines the constructs as they are applied in the remainder of this thesis. In particular, this chapter defines the process innovation lifecycle, relevant process innovation components, different dimensions of open innovation, and the investigation of absorptive capacity. The methodological relevance of applying a conceptual framework is discussed in the methodology chapter (see section 4.6).

3.1 Conceptual process innovation lifecycle

A full lifecycle perspective is necessary to document how companies develop and implement new processes. The literature review identified four lifecycle stages, including ideation, adoption, preparation, and installation (cf. Salerno et al., 2015). For the purposes of analytical clarity, this thesis proposes a linear lifecycle model.

The following sections describe the stages of ideation, adoption, preparation, and installation with regard to the key themes at each stage as proposed by previous literature. The stages serve as benchmarks to group empirical data into comparable categories. This means that companies do not necessarily have to do exactly the same things at a given stage. Rather, the purpose of what they do has to be comparable. The literature provides only limited empirical evidence of the interaction with external partners throughout the lifecycle stages. Moreover, the literature is biased towards technological change. To strengthen impartiality and remain open to emerging insights the lifecycle stages do not include propositions about the possible integration of external partners in these stages.

- **Ideation** comprises all issues relating to the identification of process candidates. Ideation is triggered by opportunity or crisis (Gopalakrishnan & Damanpour, 1994; Kurkkio et al., 2011; Lager, 2000); more generally "the positive difference between aspirations and performance on some dimension relevant to the organization" (Gerwin, 1988, p. 91). Ideas for process candidates can emerge serendipitously or through deliberate ideation methods (Cooper, 2007; Kurkkio et al., 2011; Lager, 2000), such as strategic planning, technology forecasting, brainstorming, scenario generation, interaction with internal and external experts as well as desk research, or process benchmarking (Cooper, 2007; Lager, 2000).

- **Adoption** comprises all activities necessary to make an investment decision about which process candidate to invest in. Concept development and preliminary process descriptions are necessary to describe solutions in more detail and to obtain approval and generate acceptance from relevant stakeholders (Jensen & Westcott, 1992). Despite concept development, uncertainty and equivocality often remain. Nevertheless, commitment is necessary because limited resources impede detailed investigation of all potential solutions before decision making (Cooper, 2007; Frishammar et al., 2011; Gerwin, 1988).

- **Preparation** includes all activities that contribute to technology development and organizational change planning. During this stage the technology is developed in detail, and operators can suggest further changes to a process (Tyre & Hauptman, 1992). Preparation is also important when it comes to organizing the installation of a new process (Lager, 2011; Tyre & Hauptman, 1992). This also includes planning and developing "new skills, attitudes, systems, procedures, and social structures [which] are needed by the operating and technical people responsible for running, maintaining, controlling, and organizing the innovation" (Gerwin, 1988, p. 91).

- **Installation** includes all activities that are necessary for process implementation and start-up (Tyre & Hauptman, 1992; Voss, 1992). This involves technology installation, organizational change introduction, and handing over the process to operators. During installation the consequences of change become fully apparent to organizational stakeholders and social uncertainty increases (Gerwin, 1988; Rogers, 2003). Conflict may arise from discrepancies in expectations and performance and different stakeholder perspectives. As a result, further adjustment to the process is often necessary during installation (Leonard-Barton, 1988).

- **The relevant actors** during the process innovation lifecycle are task forces, decision makers, and operators. Task forces are responsible for managing the innovation project and the interaction with external partners. Decision makers are higher-level managers and responsible for authorizing the task force's proposals. Operators include working personnel that use processes. This may include staff from technical and administrative functions. The different groups are used for analytical purposes. They are not exhaustive and may overlap to some extent.

3.2 Definition of process innovation components

The literature review showed that companies commercialize technological process innovation internally. Process innovation requires internal technology specialists and innovation champions. It involves the mutual adaptation of a new technology and the existing organization. Process innovation therefore results from technological and organizational change. Because change occurs within the organizational system, process innovation can lead to systemic impact. The present thesis dissociates the components underlying process innovation to understand how external contributions may affect each one of them at different lifecycle stages. The following sections describe the application of the components in the present thesis. In particular, the thesis focuses on studying these components in terms of the activities, outputs, and challenges that express them.[16]

- **Mutual adaptation** refers to the deliberate, reciprocal coordination of technological and organizational change to overcome misalignments between a new technology and an existing organization (Leonard-Barton, 1988; Tyre & Orlikowski, 1994). Mutual adaptation comprises technological and organizational change but refers to the coordination of both. It provides a perspective on managing the reciprocity between them. The present thesis investigates mutual adaptation prior to operation. In particular, the study focuses on the activities, outputs, and challenges related to mutual adaptation at any given lifecycle stage.

- **Managing technological change** comprises all activities, outputs, and problems related to the identification, development, modification, and implementation of new process technology. Process technology refers to any hardware and software that transforms inputs into outputs in a company's enabling and core processes (Carrillo & Gaimon, 2002; Schallock, 2010). Companies can acquire new technology or technological components by internal development, acquisition from external source, or a combination of both (Lager, 2011). Technological change does not refer to idiosyncratic technology change in specific projects. Instead, it describes the managerial activities, outputs, and challenges related to the domains of a technology's relative advantage, complexity, compatibility, and observability/communicability (Rogers, 2003; Tornatzky & Klein, 1982) (see Appendix 2: Technological innovation attributes).

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[16] The thesis studies management as performing activities to create outputs, and coping with challenges. The literature shows innovation management involves various activities to develop and implement innovations. Outputs need to be created at each lifecycle stage to provide input for the next stage. Throughout development and implementation, organizational actors face challenges they need to resolve. Therefore: Activity refers to the performance of a specific function or task by an organizational unit. Output is produced by the activities of an organizational unit. Challenges describe difficulties, problems, and risks involved in performing certain activities or achieving certain outputs.

- **Organizational change** describes the coordination, planning, and implementation of changes to work organization (Edquist et al., 2001). This includes changes to organizational structures, management methods, existing processes and operating capabilities (Carrillo & Gaimon, 2002; Damanpour & Aravind, 2012). Organizational change may affect administrative functions (Damanpour & Aravind, 2012), as well as core operations (Birkinshaw et al., 2008; Edquist et al., 2001). It may affect multiple stakeholder groups with different interests, expectations, and requirements. The coordination of organizational change to avoid conflict is thus a key challenge for the development and implementation of new processes. Nevertheless, it may enable technological change (Hollen et al., 2013) as well as limit or trigger further technological change by means of mutual adaptation (Leonard-Barton, 1988). For purposes of this thesis managing organizational change comprises all activities, outputs, and challenges related to the coordination, planning, and implementation of changes to existing structures, processes, and operating capabilities across different parts of the organization.

- **Systemic impact** describes the emergent, not necessarily linear, repercussions caused by process related change beyond the focal point of process introduction. Mutual adaptation, technological change, and organizational change occur within a broader organizational system, which is defined by the interconnection of various subsystems (e.g. technological infrastructure, operating environment, structure of departments and functions, as well as existing organizational processes) (Gatignon et al., 2002). Technological and organizational change as well as process integration can require further "follow-up" changes within the broader organizational system as well as to the design of the new process itself (Gopalakrishnan et al., 1999; Smart et al., 2009). This introduces an element of complexity which makes it necessary to account for potential emergent properties, non-linear effects, and follow-up changes (Maddern et al., 2014). The present study investigates activities, outputs, and challenges related to managing systemic impact. In particular, this includes a focus on the assessment of potential impact and on coping with systemic repercussions.

Summary: From an aggregate perspective the components of process innovation can be summarized as follows: (Technological) process innovation comprises technological change to adjust new technology to the existing organization as well as organizational changes to accommodate new technology. In this context, mutual adaptation describes the coordination of both with each other. Mutual adaptation therefore provides a perspective on managing the interactive nature of technological and organizational change with the aim of achieving a fit between new technology and organization. Mutual adaptation, technological change, and

organizational change occur within the broader organizational system (e.g. people, technology, processes, structures, and the linkages between them). Systemic impact management is necessary to coordinate reciprocal effects between the broader organizational system and technology and organization change. The development and implementation of new processes may therefore require not only a focus on individual but on all components that constitute process innovation in order to manage the activities, outputs, and challenges relating to process development appropriately (Figure 15).
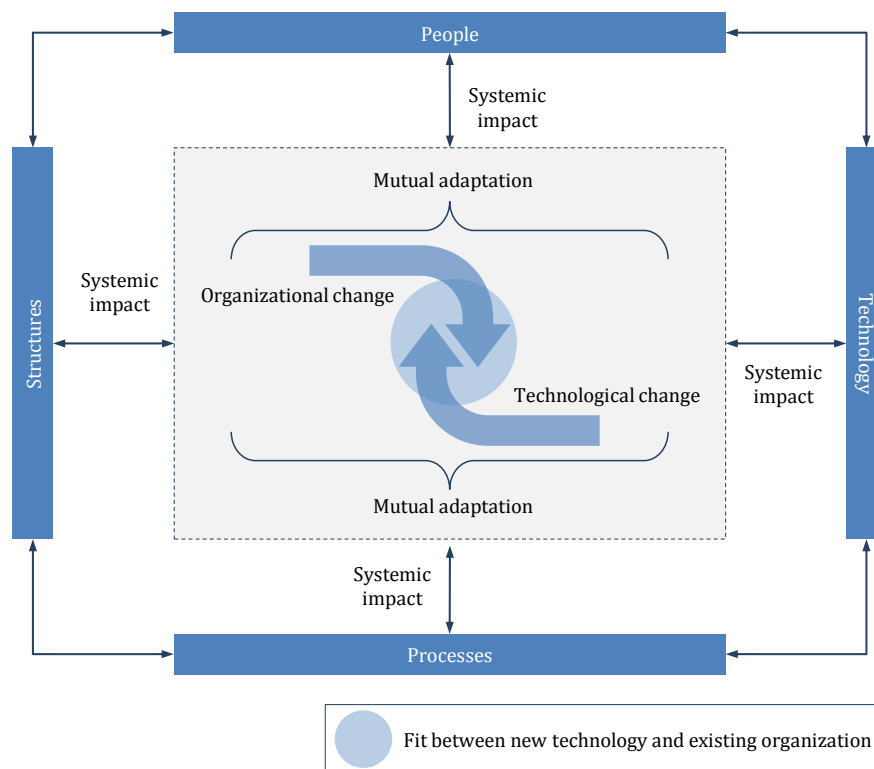
Figure 15: Process innovation model

3.3 Motivation for interaction with external partners

The motivation for open process innovation refers to the purpose for which companies interact with external partners. It describes the "why"-dimension of open process innovation (Lager & Frishammar, 2010, 2012). The motivation to engage in (inbound) open innovation is manifold and may target various types of external partners (Bianchi et al., 2011; Chiesa & Manzini, 1998; Laursen & Salter, 2006). Existing research on open process innovation has mainly emphasized motivations relating to external contributions to technology change (Lager & Frishammar, 2012; Reichstein & Salter, 2006; Rönnberg-Sjödin, 2013; Terjesen & Patel, 2014). The present thesis

investigates the motivation for interaction with regard to all four process innovation components (mutual adaptation, technological change, organizational change, systemic impact). In particular, it explores motivation with a focus on the activities that external partners support, the outputs that external partners deliver or help to create, and the challenges that they help to address.

3.4 Qualitative approach to the investigation of openness

3.4.1 Openness as search breadth and depth

Openness describes a company's engagement with external knowledge and technology for value creation. Search breadth and depth are well-established measures of openness (see section 2.3.4.2). By managing openness, companies seek to balance access to sufficiently diverse external knowledge with adequate efficacy of accessing it (Sofka & Grimpe, 2010). Openness therefore results from deliberate managerial decision making about which sources to access and how to access them (Gottfredson et al., 2005; Stock & Tatikonda, 2004). This thesis investigates openness at different stages of the process innovation lifecycle, i.e. "where the work gets done". The purpose thereof is to link openness to the motivation for interaction, and thus to the different components of process innovation. In the context of the present thesis, search is defined as a company's interaction with external partners when looking for and accessing new knowledge and technology. The following sections define how search breadth and depth are operationalized in the remainder of this thesis.

Breadth: Search breadth is often measured as the cumulative number of external partners that a company engages with in order to access external knowledge and technology (Katila & Ahuja, 2002; Laursen & Salter, 2006; Leiponen & Helfat, 2010; Terjesen & Patel, 2014). Search breadth requires managerial attention because different types of external partners encompass "different institutional norms, habits, and rules, often requiring different organizational practices in order to render the search processes effective within the particular knowledge domain [...]" (Laursen & Salter, 2006, p. 133). Against this backdrop, investigating the composition of breadth provides valuable insight beyond counting the number of external sources (Horváth & Enkel, 2014). At the project level, Horvarth and Enkel, for example, describe breadth as the number of potential partners and the criteria for selecting external partners. The thesis at hand investigates search breadth at the level of individual lifecycle stages. Specifically, search breadth describes the qualitative composition rather than merely the aggregate number of a company's external partner diversity. In addition, the study investigates the rationale behind the composition of search breadth, i.e. the potential link between search breadth and the motivation for interaction.

Depth: Search depth is often measured as the perceived intensity with which a company draws on external knowledge or technology contributions (Laursen & Salter, 2006; Sofka & Grimpe, 2010; Terjesen & Patel, 2014). Such approaches focus on the importance of external contributions rather than on the content of relational interaction (Bahemia & Squire, 2010). Yet, the transfer of knowledge and technology across company boundaries is an interactive process. Therefore, "successful collaboration depends on adequate management of information flows and sharing of knowledge among stakeholders..." (Lager & Frishammar, 2010, p. 702). In light of these ideas, the present thesis investigates search depth as the structure of interaction between a company and its external partners. The sub-dimensions that describe interaction include the exchange of information with external partners (communication), joint planning activities (coordination), and work performance distribution (cooperation) (Bahemia & Squire, 2010; Stock & Tatikonda, 2004). This thesis investigates the depth dimensions of interaction at the lifecycle stage level along these sub-dimensions, which are further outlined in the following.

- **Communication** describes the information exchange between a company and an external partner. Scholars often assume that greater degrees of communication facilitate more successful technology transfer (Utterback, 1971). While frequent information exchange can reduce uncertainty it can also have adverse effects such as "overloading" organizational stakeholders (Mohr & Nevin, 1990) or increasing equivocality (Frishammar et al., 2011). Further insight can thus be gained from assessing content and the quality of information exchange. The content of information exchange during inter-organizational interaction may be technical or administrative in nature. The former relates to the main work subject of the interaction, while the latter refers to the coordination of such work (Tatikonda & Stock, 2003). Moreover, the content of information exchange describes the extent "to which critical, often proprietary information is communicated to one's partner" (Mohr & Spekman, 1994, p. 139). The quality of information exchange can range from unspecific, "poorly codified, poorly structured, and [ambiguous]... to very specific, detailed, organized, and unambiguous" (cf. richness) (Tatikonda & Stock, 2003, p. 457). Moreover, the quality of information exchange in terms of timeliness, adequacy, and credibility further affects the success of inter-organizational interaction (Mohr & Spekman, 1994). In this thesis, information exchange describes the extent to which there is mutual exchange of specific, potentially critical, process related information between the company and an external actor at a given stage.

- **Coordination and cooperation** describe the structure of interaction. Coordination refers to the formality involved in the interaction (Tatikonda & Stock, 2003). Cooperation refers to the distribution of work responsibilities; i.e. who performs the

work? (Lager & Frishammar, 2010; Rönnberg-Sjödin & Eriksson, 2010). In-depth interaction involves close collaboration for joint problem solving. In less in-depth interaction, companies and external partners work on separate issues and only present each other with final results (Horváth & Enkel, 2014). Formality describes the degree to which work is pre-planned, structured, and rigid (Mohr & Nevin, 1990; Stock & Tatikonda, 2000). Formality can enhance efficiency by providing structure and explicating objectives, as well as assigning specific work responsibilities and liabilities (Rönnberg-Sjödin & Eriksson, 2010; Stock & Tatikonda, 2000). On the other hand, excessive formality can restrain efficiency (Eisenhardt & Tabrizi, 1995), decrease trust and increase opportunism due to an exaggerated focus on guidelines rather than common goals (Heide & John, 1992). Likewise, in-depth interaction not only requires a clear specification of attainable goals, but also trust, commitment (willingness to dedicate the necessary effort to a particular common goal), and flexibility (Tatikonda & Stock, 2003). Flexibility is particularly relevant when specific problems involve tacit knowledge and a high level of uncertainty and equivocality (Fliess & Becker, 2006). Formality can provide the institutional frame for collaboration, but in-depth interaction also involves flexibility and joint problem solving to address uncertainty and equivocality (McEvily & Marcus, 2005).

Based on the sub-dimensions of search depth as outlined above, the present thesis distinguishes between three different degrees of interaction depth (Table 8).

Table 8: Different degrees of depth

Degree of depth	Definition
Strong	Interaction involves substantial mutual exchange of specific, potentially critical, process related information between the company and an external actor for technical problem solving. There is formality and close collaboration: tasks and objectives are defined but there is flexibility for conjoint problem solving
Medium	Interaction involves some mutual exchange of specific, potentially critical, process related information between the company and an external actor for technical problem solving. There is formality but no close collaboration: tasks and objectives are defined, there is some flexibility for problem solving but little to no conjoint problem solving
Weak (1)	Interaction involves little or no mutual exchange of specific, potentially critical, process related information between the company and an external actor for technical problem solving. There is formality but no close collaboration: tasks and objectives are clearly defined, structured, and rigid
Weak (2)	Interaction involves no specific information, no formality, and no close collaboration

Knowledge sharing and protection: The interaction with external partners for knowledge and technology transfer in open innovation presents companies with a tension between knowledge sharing and protection (Bogers, 2011; Hurmelinna-Laukkanen, 2011). On the one hand, companies have to share internal knowledge with external partners by providing relevant information. This is particularly difficult when internal knowledge is systemic, complex, and tacit (Gopalakrishnan & Bierly, 2001). On the other hand, the literature review showed that companies typically appropriate process innovation by means of secrecy (James et al., 2013). As a result companies must protect their knowledge from unintended use through legal as well as non-legal methods (Rönnberg-Sjödin & Eriksson, 2010; Slowinski et al., 2006). As knowledge exchange occurs on the operational level legal methods (e.g. non-disclosure agreement) are of limited value (Hamel et al., 1989; Slowinski et al., 2006). Against this background companies have to manage the interaction with external partners in a way that balances knowledge sharing and protection on the operational level. The present thesis explores whether and how this tension affects companies' approaches to open process innovation. To capture potentially emerging insights, the study includes an open inquiry about the general role of formal and informal practices in relation to knowledge sharing and protection throughout the different stages of the innovation lifecycle (see Appendix 6: Interview guide II (November and December 2013) for interview items on knowledge sharing and protection).

3.4.2 Routine-based investigation of capability deployment

The literature suggests that absorptive capacity is a necessary prerequisite for the management of knowledge and technology transfer in open innovation (Lichtenthaler & Lichtenthaler, 2009; Spithoven et al., 2011; Vanhaverbeke et al., 2007). Absorptive capacity includes different capabilities (e.g. knowledge recognition, assimilation, transformation, and exploitation) (see section 2.3.5.1). The present thesis aims to investigate the deployment of capabilities across the innovation lifecycle as companies absorb new knowledge through interaction with external partners. Capabilities are not directly observable, but are reflected in meta-routines, which comprise various observable, practiced routines (Lerch et al., 2012; cf. Lewin et al., 2011; Müller-Seitz, 2012). This thesis, therefore, approaches the study of AC capability deployment with regard to the observable practices by which companies engage in interaction with external partners. Empirical data on the activities, outputs, and challenges related to process innovation components, motivation for interaction, and openness provide insight into routines and practices of managing the interaction with external partners. Following the routine-based approach to the investigation of AC this provides the basis for the discussion of knowledge absorption in open process innovation at different stages of the innovation lifecycle (see again Section 2.3.5.2: The underlying constituents of absorptive capacity).

3.5   Summary of conceptual framework

In summary, the framework guiding the present study comprises three a priori constructs of open process innovation: process innovation components, the motivation for interaction, and openness. Each construct is further defined and operationalized in terms of it sub-items. These constructs are mapped across a generic four-stage innovation lifecycle. This results in the conceptual categories in which to the external contributions to different process innovation components, as well as the motivation for interaction, and the configuration of openness at different stages of the innovation lifecycle can be explored (Figure 16). The results of mapping empirical data using the conceptual framework will enable the discussion of open process innovation, including a discussion of the deployment of absorptive capabilities.
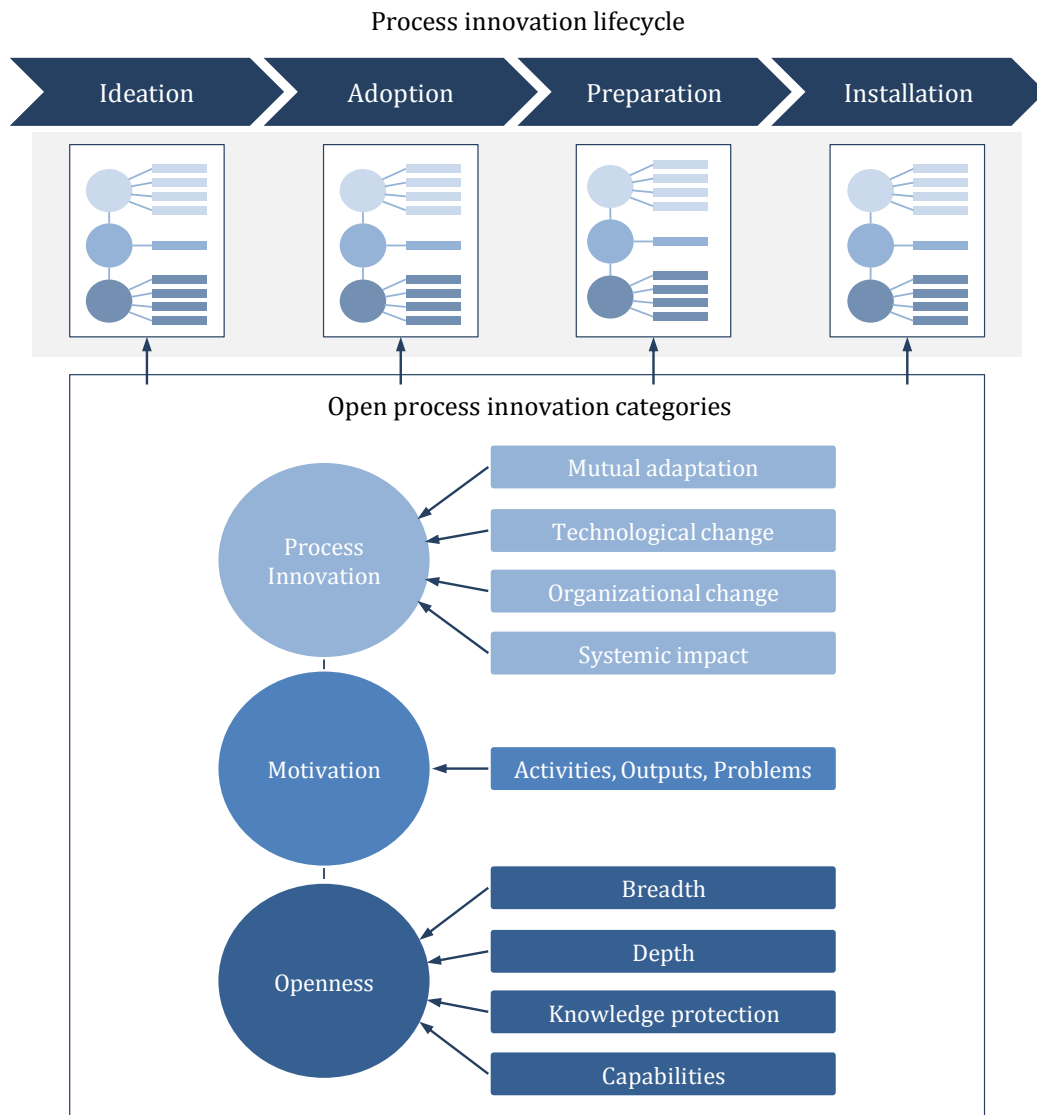
Figure 16: Conceptual research framework

4 Research methodology

This chapter introduces the details of the research methods that were applied in this thesis. The chapter first outlines the underlying philosophical assumptions of this study, introduces case-based research as a scientific method, and provides a justification of adopting a case-based research design. Afterwards the chapter explains the case selection and data collection procedures that were applied for this study. In order to achieve transparency and credibility, a particular focus is then put on the analytical procedures that lead from data to findings. Finally, the chapter concludes with an outline of the measures taken to ensure validity and reliability.

4.1 Philosophical assumptions

Research philosophy describes the scientific positioning of scholarly inquiry regarding ontological and epistemological assumptions. Ontology refers to the philosophical discourse on the nature of reality (Wand & Weber, 1993). Epistemology describes the philosophical discourse on the nature of knowledge about reality and how it can be acquired (Burrell & Morgan, 1979). A study's underlying philosophical assumptions determine the adequacy of the research design chosen for that particular study (Guba & Lincoln, 2000). The present thesis subscribes to an ontological perspective of an objective reality, in which structures and subjects exist independently of the existing knowledge about them. This implies that technologies, processes, and operators exist and are independent of external perception. The thesis further subscribes to an epistemological perspective in which knowledge about reality is mediated by social actors' perception of it. Open process innovation as an organizational phenomenon involves the interaction between social actors that make sense of what they do. This philosophical positioning resembles the critical realist tradition (Bhaskar, 1975). Critical realism asserts that the world exists independently of external perception or knowledge but access to social interactions within the world remains socially mediated (Bryman & Bell, 2007). In this context, critical realism posits that the "study of the social world should be concerned with the identification of the structures that generate that world" (Bryman & Bell, 2007, p. 726). In order to understand open process innovation as an organizational phenomenon, this thesis investigates the empirically observable events of open process innovation and by abstraction moves to the general and objective constructs that govern the mechanisms of open process innovation. Although knowledge generated this way may never be accepted with perfect certainty, propositions about reality enable research to falsify them by controlling for their effects in the real world (Mingers, 2002). Case-based research is particularly suited for construct

development to facilitate propositions about real world entities, structures, and the relationships between them (Easton, 2010).

4.2   Case-based research as a scientific method

Case research is a powerful scientific method which generates insightful and robust contributions to knowledge and practice (Eisenhardt & Graebner, 2007; Pratt, 2009; Stuart et al., 2002; Voss et al., 2002). According to Yin (2003), a case study is an objective and in-depth examination of a contemporary phenomenon where the investigator has little control over the empirical events. The case-based approach is particularly suited to facilitate exploratory studies when relevant prior theory is underdeveloped and the boundaries, key processes, and constructs of the phenomenon under investigation are not fully known at the outset of the study (Barratt et al., 2011; Benbasat et al., 1987; Darke et al., 1998; Edmondson & McManus, 2007; Eisenhardt, 1989; Yin, 2003).

Case research is particularly important in contexts that are complex and characterized by "interplays of people, technological systems, and organizational and physical processes, most of which change in their nature over time" (McCutcheon & Meredith, 1993, p. 248). Such settings are characteristic for the development and implementation of new processes. Testing theories about such settings depends on substantial knowledge about the relationships and interaction between key variables (McCutcheon & Meredith, 1993). The literature review in this thesis showed that this is not given in the case of managing open process innovation across the innovation lifecycle. In order to understand the underlying principles and causal mechanisms of open process innovation, an in-depth engagement with the phenomenon is necessary.

Case-based approaches typically involve the study of rich and detailed qualitative data (Edmondson & McManus, 2007). This provides an opportunity for "obtaining new holistic and in-depth understandings, explanations and interpretations about previously unknown practitioners' rich experiences" (Riege, 2003, p. 80). Such insights help understand the conditions under which theoretical constructs are applicable. Furthermore, they offer an opportunity to substantiate potential causal relationships by observation and by documenting an analytical chain of evidence that illuminates the underlying mechanisms of specific phenomena (Stuart et al., 2002). Against this background, there are three particular strengths of case-based research, as Voss et al. (2002, p. 197) point out: (1) In case-based research, phenomena can be studied by observation of actual practice in a real-world environment; (2) case-based research can address why, what, and how-type questions with a relatively comprehensive understanding of complex phenomena and the context in which they occur; and

(3) the case-based approach is applicable for exploratory investigation when relevant parameters are unknown and phenomena are not well understood.

Generally, the literature agrees that case research is applicable for different purposes, including theory-building/construct development, refinement and elaboration, or testing (Eisenhardt & Graebner, 2007; Ketokivi & Choi, 2014; McCutcheon & Meredith, 1993; Stuart et al., 2002; Voss et al., 2002; Yin, 2003). In this context, Barrat et al. (2011) further distinguish between theory-driven and phenomenon-driven case research. Theory-driven research is mainly driven by the deductive application of a specific existing theory (e.g. transaction cost economics, resource-based-view, etc.). In contrast, phenomenon-driven research focuses on the study of a specific phenomenon. Instead of applying one specific theoretical lens, it is informed by a various potentially relevant streams of literature. The present thesis is positioned within the group of phenomenon-driven, exploratory, construct-developing case research.[17]

4.3 Rationale for adopting a case-based research design

Internal consistency between the different elements of a research project, such as research question, theoretical background, research design, and emerging constructs is a necessary precondition for creating valid knowledge contributions from field research (Edmondson & McManus, 2007). In this context, it is imperative to provide justifications for the use of theory-building case research (Eisenhardt & Graebner, 2007). With regard, to the particular strengths of case-based research, typical justifications include theoretical paucity, meaning that a phenomenon is insufficiently explained by existing literature or theory; addressing how, why, and what-type questions; the importance of capturing a complex phenomenon in context and taking managerial experiences into account, in order to increase the relevance for practical application (Barratt et al., 2011; Stuart et al., 2002; Voss et al., 2002). The present study applies case-based research due to the limited amount of existing research and theoretical paucity and because it aims to capture a complex and dynamic, real-life phenomenon.

Limited existing studies and theoretical paucity: The existing theory on open process innovation is currently developed to a state between nascent and intermediate (cf. Edmondson & McManus, 2007). As outlined above, there are a limited number of studies on open process innovation from a lifecycle perspective. The existing literature offers initial insights on the phenomenon but remains limited in various ways (see section 2.7). Nevertheless, it would be a mistake to ignore other, more general theories that may be relevant to a specific phenomenon (Stuart et al., 2002). The literature review in this study showed that open process innovation

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[17] Fur the purposes of this thesis theory-building and construct development are used interchangeably.

draws on a variety of subjects from the broader management literature (e.g. exploration-exploitation; absorptive capacity; technology transfer). Due to the limited prior research, at the outset of this study the understanding of open process innovation as an organizational phenomenon was "fuzzy", i.e. its boundaries were not obvious. In particular, existing theory lacks the constructs to make comprehensible and consistent predictions about how and why companies work with external partners for process innovation along the stages of the innovation lifecycle. Theory-building research is necessary to understand the underlying principles of open process innovation. Conversely, deductive research approaches are less applicable for the present study (cf. Stuart et al., 2002). While existing theories and different streams of literature inform the development of general categories for this study, they do not enable predictions about the occurrences of open process innovation at different lifecycle stages. Any attempt to do so would artificially limit or bias the research, ultimately leading to the discrimination of valuable insights (Ketokivi & Choi, 2014). Instead, it is necessary to engage with the phenomenon in a way to allow findings to emerge from the data rather than try to impose limitations on it by hypothesizing on potential outcomes with the limited theory available. Case-based research is therefore the most suitable approach for the purposes of the present thesis, given its strength in addressing "how-and-why" and exploratory "what" type questions (Yin, 2003).

Capturing a complex and dynamic real-life phenomenon: The management of external collaboration for process development and implementation is a complex organizational phenomenon. As suggested in the literature review, the phenomenon under investigation in this study is very complex for several reasons. Process innovation, as defined in the present study, is a systemic construct that involves technological and organizational aspects. The development and implementation of new processes therefore requires managing the mutual adaptation of technological and organizational change within an existing organizational frame. Open innovation at the operational level involves the interaction with a variety of external actors, as well as interaction with a variety of internal stakeholders. Finally, the lifecycle perspective adds a dynamic perspective to the phenomenon in which the activities, expectations, requirements, and perspectives of stakeholders may be subject to change (cf. Lager, 2011). As such the phenomenon is embedded in the organizational, social, and time-dependent context in which it occurs and therefore does not provide opportunities for control over the events. Case research is particularly suited for contemporary research and for when there is no control over the empirical events (Yin, 2003). Open process innovation needs to be studied with regard to the time-dependent content of process innovation components, motivation for interaction, and openness. Understanding how and why processes unfold and pointing out time-dependent relationships are research objectives that are conducive to case-based theory building research

(Edmondson & McManus, 2007; Stuart et al., 2002). However, these factors are interlocked and the different categories across the stages of the innovation lifecycle have to be considered as a coherent whole in order to capture the dynamic nature of managing open process innovation. This creates such a complex situation, involving a number of variables and possibly relevant relationships for which other methods (e.g. survey research) are unlikely to be efficient or to provide feasible ways of capturing the coherency, richness, and complexity of the phenomenon of interest. This setting makes it necessary to apply case-based research as a method providing the right tools to capture "… and disentangle a complex set of factors and relationships, albeit in a small number of instances" (Easton, 2010, p. 119).

4.4   Case selection and overview

Multiple case study design: The study follows a multiple case study design for theory building on open process innovation management. More specifically, the present study includes five different companies. Barrat et al. (2011) particularly emphasize the importance of multiple cases for theory building research, as multiple cases are more likely to create robust and testable theory. It may be argued that single case provide a better opportunity to capture significantly more context and detail, they are more suited for longitudinal research (Voss et al., 2002) and investigating extreme cases or exploiting unique access to a specific empirical setting (Yin, 2003). However, multiple cases are likely to provide strong theory because results are grounded in varied empirical evidence and it can more readily be identified whether the findings are idiosyncratic to a specific case or apply more generally across multiple cases (Eisenhardt & Graebner, 2007). Eisenhardt (1989) suggests that less than four cases make it difficult to capture the complexity of a specific phenomenon, whereas more than ten cases make it difficult to cognitively process the overwhelming amount of information. Furthermore, case studies are subject to the law of diminishing returns, which means that repeated evidence adds little value to the emergent findings (Stuart et al., 2002). Therefore, cases should be selected according to the value they add to the study rather than for quantitative purposes.

Theoretical sampling: For this thesis, cases were deliberately selected to maximize the insight that could be gained from a limited number of cases given the time available. In case-based research, cases are selected for specific reasons rather than seeking random distributions (Barratt et al., 2011). Cases can, for example, be chosen to replicate or extend previous cases, they can fill theoretical categories or provide illustrative examples of particular types of companies (Eisenhardt, 1989). To this background "theoretical sampling" refers to choosing cases that are particularly illuminating for a specific phenomenon (Eisenhardt & Graebner, 2007). It is frequently argued that theoretical sampling for theory building should follow a

replication logic (Yin, 2003). Replication logic means that cases are selected for which similar results are predicted (literal replication), or such for which contrasting results are predicted (theoretical replication). However, replication logic as suggested by Yin presupposes a rich underlying theory that allows for predictions on the conditions under which a phenomenon occurs or not occurs. This is not feasible for this thesis, as the present study follows a more open approach for theory building and deliberately refrains from adopting a specific theoretical lens. Relevant cases were, therefore, selected based on their potential contribution to construct development, as outlined in the following (Eisenhardt & Graebner, 2007).

Case selection criteria: For the present study, cases were chosen according to pre-defined criteria to ensure the phenomenon of open process innovation was likely to occur (see Appendix 3: Case selection criteria). The deliberate case selection provided a common ground for cross-case comparison within the scope of technological process innovation in large manufacturing companies. In this regard the selection process focused on large manufacturing companies with strong investments in externally developed technologies, and process innovation *(first order criteria)*. While keeping these criteria constant, variation among the cases was created in order to capture further potential aspects of open process innovation. The type of process (enabling vs. core) and project scope (narrow vs. broad) were thus chosen as the different criteria along which to replicate or contrast the results of the different cases *(second order criteria)*. The first and second-order selection criteria were mostly informed by previous literature. Miles and Huberman (1994) call this stratified purposeful sampling, the purpose of which is to "illustrate subgroups and facilitate comparison" (p.28). This approach is particularly suited to "maximize the utility of information from small samples and single cases… to obtain information about the significance of various circumstances for case process and outcome" (Flyvbjerg, 2006, p. 230).

Case overview: In total ten companies were contacted, of which eight agreed to participate (see Appendix 4: Case selection process). Two of the potential candidate cases turned out to be irrelevant given that the focus of the potential interviewees did not relate close enough to technological process innovation as defined in this thesis. AIRBUS became a pilot study because of the limited amount of accessible participants. This involved several interviews with a key respondent and served the purpose of test, refine, and practice the interview guides, conceptual framework, and data analysis procedures.The study therefore includes five cases, namely:

- BMW
- Knorr-Bremse Rail Vehicle Systems
- Thyssen Krupp Marine Systems
- ZF Friedrichshafen
- TE Connectivity

With regard to the second order criteria the following selection emerged among the companies (Table 9).

Table 9: Case selection overview

Company	Type of process	Project scope
BMW	Enabling	Broad
ZF Friedrichshafen	Enabling	Broad
Thyssen Krupp Marine Systems	Enabling	Narrow
Knorr-Bremse	Enabling	Narrow
TE Connectivity	Core	Narrow

All cases provided some additional information on the other type of process than the type of process they mainly reported on. This counterbalances the limitation of having only one company reporting mainly on core process development. Where necessary this is clearly marked in the results.

4.5 Methods and tools for data collection

The data for this study were mainly collected in two rounds of semi-structured interviews (January and February, November and December) in 2013. The following sections provide details on the different data sources that informed this study as well as on the preparation and conduct of data collection.

4.5.1 Data sources and triangulation

The empirical data for this study were collected through semi-structured interviews as well as field notes taken during visits to research and development facilities, as well as from internal company records and presentations. The use of multiple data sources is a major strength and distinctive feature of case-based research and serves the purpose of data triangulation i.e. corroborating the same finding from multiple sources (Barratt et al., 2011; Yin, 2003). Triangulation increases the reliability of empirical insights. It substantiates emergent constructs and propositions when the data from multiple sources lead to converging results (Barratt et al., 2011; Eisenhardt & Graebner, 2007; Eisenhardt, 1989). Furthermore, missing information from one source could be filled by additional information from other sources. Finally, multiple sources were assumed to balance potential biases in individual sources and create a richer picture of the individual cases.

Typical data sources for case-based research include interviews, observation (e.g. plant tour, attendance at meetings), and archival records (e.g. documents, historical records, organizational charts, and production statistics) (Barratt et al., 2011; Eisenhardt, 1989; Voss et al., 2002). The

present study used a variety of data sources. First and foremost, the present study was informed by semi-structured interviews with knowledgeable representatives from the different case study companies. Key contacts at each company were consulted in order to identify relevant interviewees. All interviewees had at least five years of experience in process development and implementation at the time of data collection. Furthermore, "snowball sampling" was applied, in which interviewees were asked to suggest further interviewees. The interviews lasted between 30 minutes and 2.5 hours. In total there were 32 participants and 55 interviews, which yielded around 91.5 hours of interview data, excluding pilot and follow-up interviews. An overview of the participants and interview meta-data is provided inTable 10.

Table 10: Data overview

Company	No. interviewees		No. interviews	Interview hours	Additional data
BMW	4	[R1-R4]	7	10.5	▪ Secondary data
Knorr-Bremse	4	[R5-R8]	9	15	▪ Field notes ▪ Secondary data
Thyssen Krupp Marines Systems	8	[R9-R16]	12	20	▪ Field notes
TE Connectivity	9	[R17-R25]	14	23.5	▪ Field notes ▪ Secondary data
ZF Friedrichshafen	7	[R26-R32]	13	22.5	▪ Field notes ▪ Secondary data
Total	**32**		**55**	**91.5**	

[Rx] is used as the identifier for the individual respondents that participated in this study

4.5.2 Preparation and conduct of data collection

Multiple rounds of data collection: Data were collected in two rounds. The first round primarily focused primarily on the management of process development and implementation. The second round primarily focused on managing external contributions to process development and implementation(see Appendix 5: Interview guide I (January and February 2013) and Appendix 6: Interview guide II (November and December 2013)). This approach was necessary to facilitate data collection on a relatively large and complex topic which otherwise would have required excessively long interviews. Long interviews are difficult to conduct as interviewees may lose interest, become reluctant to participate, or find it difficult to stay focused which may lead to corrupted data. Multiple rounds of data collection, on the other hand, provided the opportunity to analyze the data and adjust the focus of the inquiry based on initial insights. Likewise, multiple rounds of data collection facilitated the clarification and convergence of findings, especially when the initial data analysis revealed areas of lacking or conflicting

information. Finally, it was possible to focus the second round of data collection on those interviewees that provided particularly interesting information and include further potentially relevant interviewees.

Preparation of semi-structured interviews: Interview data were collected through face-to-face interviews with knowledgeable company representatives. Follow-up interviews were held over the telephone. All interviews were semi-structured. They followed an interview guides which outlined main topics, yet allowed for probing and exploration of further important topics that emerged during the interviews (Bryman & Bell, 2007; Kvale, 1996; Rubin & Rubin, 2012). The interview guides for each round of data collection were systematically developed with regard to the initial research framework and aimed to set the focus of inquiry on the different categories of open process innovation (see Appendix 5: Interview guide I (January and February 2013) and Appendix 6: Interview guide II (November and December 2013)). Developing the interview guides began by outlining topics that were relevant for addressing the research questions. Then, several questions were noted to inquire about these topics. The questions were rephrased and changed repeatedly in order to avoid confusing or ambivalent terminology. Questions were phrased in a way not to imply specific answers. The interview guides were revised after review by other expert scholars (n=3), practitioners (n=2), and initial pilot interviews (n=2). The development of the interview guides was documented in a case study database (Voss et al., 2002; cf. Yin, 2003). During the interviews, observations and note-taking were useful to capture initial impressions and reflection after each interview. This also facilitated an overlap of data collection and early data analysis. As a result, the interview guide could be adjusted to emergent themes. This was particularly useful for the theory-building purpose of the study where "investigators are trying to understand each case individually and in as much depth as feasible" (Eisenhardt, 1989, p. 539).

Retrospective interviews on general experiences: The interviews were retrospective, focusing on the interviewees' general experience with open process innovation rather than specific projects. This approach proved very useful given that the study focused on general patterns of open process innovation rather than company- or project-specific issues. Although, various examples were discussed during the interviews to illustrate different issues, the reports were not subject to idiosyncratic, individual projects. Instead, they reflected more general issues related to the management of open process innovation. The rich experiences of the interviewees helped to identify important themes and ultimately new theoretical insights on open process innovation. Despite the appropriateness of retrospective data for the purpose of the present study, it is sometimes argued that retrospective data lacks the level of detail that might be obtained from investigating a single innovation project as a participatory researcher (Pan & Tan, 2011). Moreover, the use of any retrospective data always bears the risk of ex-post sense

making, bias, or poor recollection by the interviewees (Eisenhardt & Graebner, 2007). A key approach for tackling these risks is the use of numerous, knowledgeable informants. If various diverse perspectives and experiences lead to similar insights regarding the focal phenomenon, it decreases the likelihood of collective bias or convergent retrospective sense-making (Eisenhardt & Graebner, 2007).

Formalities and early processing: At the outset of each interview, the purpose of the study was explained to the interviewees. Visual displays were used to facilitate a better understanding of the categories at the center of the investigation (see Appendix 7: Interview tools). All interviewees were provided with relevant information about the research (see Appendix 8: Participant information sheet). The research and research materials were approved by the University of York's Ethic Committee. The interviews were recorded which enabled a greater focus on the conversation than note taking. Only one interviewee refused to be recorded but consented to note taking. All interviews were transcribed, anonymized, and sent back to the interviewees for validation and to gather further comments (cf. Voss et al., 2002). However, this turned out to be problematic because the transcripts were long and not every interviewee replied. The original recordings were therefore kept in a database in order to ensure that the accuracy of the transcripts could be confirmed at any time. Furthermore, key contacts at each company confirmed the accuracy of the write-ups for each case, thus ensuring the accuracy of the data.

4.6 Data analysis procedures

The sections above stated that the present study adopts a theory-building, multiple-case research approach. The outcome of theory-building case research can be theoretical constructs, conceptual frameworks, propositions, suggestive models, or mid-range theory (Barratt et al., 2011; Edmondson & McManus, 2007; Eisenhardt, 1989). Nevertheless, case research lends itself primarily to theorizing about a specific phenomenon rather than developing "grand theory" about organization in general (Eisenhardt, 1989). Against this background the present thesis aims to develop theoretical constructs that capture the underlying mechanisms of open process innovation throughout the innovation lifecycle.

4.6.1 Application of a conceptual framework

Even in case based research for theory development, it is difficult to start research from a "clean slate" because this creates confusion over the role of existing theory (Eisenhardt, 1989). Even highly inductive research requires an idea of general constructs and categories that will be studied (Voss et al., 2002). To achieve transparency and clearly articulate the study's theoretical

contributions it is necessary to explicate the role of existing theory (What is the theoretical starting point? How does the research effort link to existing theories?) (Ketokivi & Choi, 2014). It is therefore frequently suggested that research should use a priori constructs and categories in order to shape the initial design of the study (Eisenhardt, 1989; McCutcheon & Meredith, 1993; Voss et al., 2002). Miles and Huberman (1994), for example, recommend explicating a research framework at the outset of theory building research to create categories or intellectual "bins" that are likely to be important for the specific phenomenon under investigation. A framework can take narrative forms of visual depiction (Miles & Huberman, 1994). A framework is different from a model, as it outlines relevant categories, but does not propose specific relationships between them (Teece, 2007).

Frameworks as initial constructs for theory-building case research typically draw on separate bodies of literature (Edmondson & McManus, 2007). They aid data collection by providing an initial focus on potentially relevant sources and topics of inquiry. By deriving potentially relevant constructs from existing literature, they can be investigated more accurately (Barratt et al., 2011; Eisenhardt, 1989; Voss et al., 2002). If the proposed constructs prove to be relevant to the study's results, a priori specification provides an opportunity to integrate the emerging results with the existing literature (Eisenhardt, 1989). It should be noted, however, that no a priori construct is guaranteed to be included in a study's findings. Despite a priori constructs, researchers have to remain open to surprise and be flexible in changing the initial framework in order to avoid not simply confirming existing pre-dispositions and finding what one wants to find (Ketokivi & Choi, 2014). In this respect, McCutcheon and Meredith (1993) argue that theoretical considerations are important to theory building research but should be kept to a minimum (p.243). Eisenhardt (1989) aptly summarizes:

> Attempting to approach this [clean slate] ideal is important because preordained theoretical perspectives or propositions may bias and limit the findings. Thus, investigators should formulate a research problem and possibly specify some potentially important variables, with some reference to extant literature. However, they should avoid thinking about specific relationships between the variables and theories as much as possible, especially at the outset of the process (p.536). [18]

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[18] This is one of the most obvious differences to the case based approach proposed by Yin (2003), who argues for the development of theory prior to data collection and analysis. Similarly, Stuart et al. argue that initial propositions may provide guidance for the researcher to structure "what results should be expected and what constitutes reasonable evidence for or against the proposition" (p.425). Such approaches argue that propositions provide focus but the researcher needs to remain flexible enough to change the propositions and research design during the early stages, if initial pilot studies reveal that important variables have been overlooked or overestimated. This was, however, not feasible in the present study, given the theory developing approach.

Following the assertions outlined above, the present study applies a set of relevant categories to provide focus during data collection and analysis. The framework developed for this study describes such categories (process innovation, motivation, and openness at different lifecycle stages) and their underlying components, that are likely to be important for the study of open process innovation (see Chapter 3: Conceptual research framework). The categories are informed by several streams of relevant literature in innovation management and operations management as well as a number of initial pilot studies that were conducted at the outset of the research project. The framework does not propose specific relationships between the different categories or speculate about their final relevance. Instead, it provides scope for findings to emerge during data analysis. Likewise, the inquiry during data collection extended beyond the framework categories when unexpected opportunities for interesting insights presented themselves. The framework provides transparency throughout the research process and helps to link findings back to the relevant literature. At the same time, however, new literature became relevant as the findings started to take shape.

4.6.2 Explicating units of analysis

The unit of analysis is the most basic category of a research project. It describes what is being investigated. It defines what the case study is about and should be derived from the main research question (Yin, 2003). Studies can have a single or multiple units of analysis (Yin, 2003). Explicating the unit of analysis is necessary to position a study within a broader body of knowledge and to define the boundaries and scope of an emerging theory (Barratt et al., 2011).

The present study focuses on open process innovation at the level of the individual lifecycle stage and at the aggregate lifecycle level. The focus on different lifecycle stages is necessary to account for the distinct characteristics of individual stages. On the other hand, lifecycle stages are interdependent, which makes it necessary to account for the development of specific themes across the innovation lifecycle. The present study therefore has two units of analysis:

(1) The management of open process innovation at the individual lifecycle stage
(2) The management of open process innovation from an aggregate lifecycle perspective

4.6.3 Duality criterion and principle of increasing abstraction

Phenomenon-driven research typically stays close to empirical data (Barratt et al., 2011; Ketokivi & Choi, 2014). Close and in-depth engagement with empirical evidence has the potential to lead to theory that accurately reflects reality (Eisenhardt, 1989). While this is a strength, meaningful results also require sufficient abstraction to go beyond descriptive accounts and identify underlying mechanisms of observed phenomena (Barratt et al., 2011).

Against this backdrop, Ketkovi and Choi (2014) propose the "duality criterion" as a necessary condition for scientific rigor in case-based research. The duality criterion posits that the theoretical constructs generated from case-based research should be deeply contextually grounded in concrete and particular empirical evidence, but at the same time provide a sense of generality to emphasize their more general, abstract theoretical implications. To meet the duality criterion, the present thesis follows a principle of increasing abstraction by moving from the empirical data, to the content of categories and sub-categories, to themes within and across lifecycle stages, and ultimately new constructs (Figure 17) (cf. Gioia et al., 2012; Saldana, 2009). Nevertheless, as the dashed ellipse in Figure 16 indicates, the outcome of the analysis process comprises a focus on both, a sense of abstraction and generality as well as deep grounding in concrete empirical data.
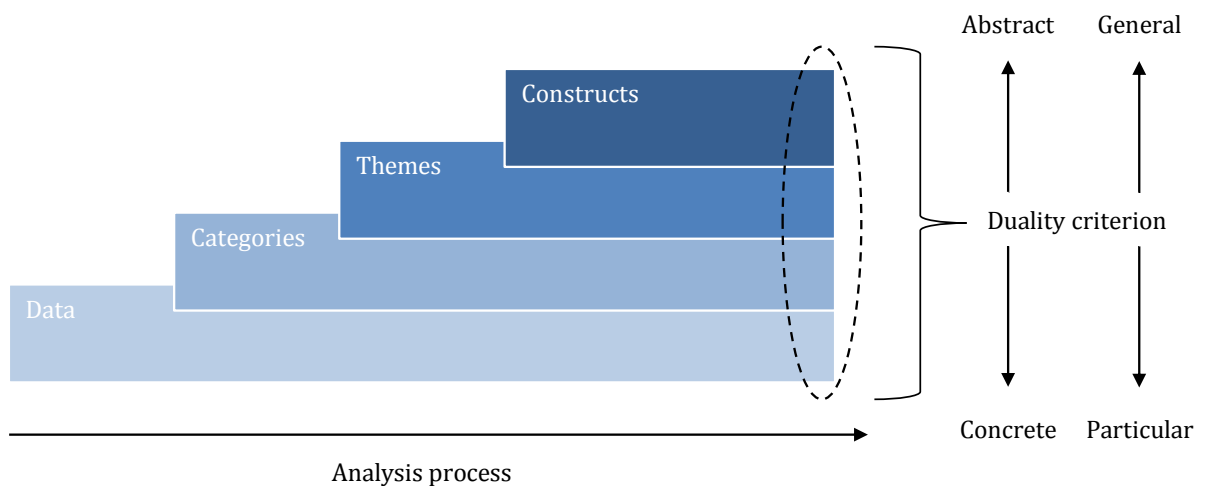
Figure 17: Increasing abstraction and duality criterion

With regard to the duality criterion, the different levels of abstraction are defined as follows. Data refer to the concrete evidence collected from practitioners. Categories refer to the theoretical "bins" into which the data was organized and that are central to the study of open process innovation from a lifecycle perspective. Themes are recurring subjects or topics within a specific context, i.e. within specific lifecycle stages. Themes may span several categories within a specific stage. For the purposes of this study theoretical constructs are defined as ideas, concepts, or theories that express general, abstract principles, mechanisms, or meanings. They are not directly observable and consist of multiple underlying elements. In the context of the present thesis constructs describe the governing mechanisms of open process innovation that emerge from the themes of open process in different lifecycle stages. The study moves from data to constructs by means of conceptualization and abstraction, which were achieved through

cross-case analysis and comparison of emerging results with other existing studies and theories (Eisenhardt, 1989; Ketokivi & Choi, 2014; Miles & Huberman, 1994). The following sections describe the specific data analysis procedures in more detail.

4.6.4   Analysis process

The analysis procedures in this study are informed by the works of Eisenhardt (1989) and Miles and Hubermann (1994). Eisenhardt (1989) outlines an approach to theory-building from case research that is distinctively characterized by within-case and cross-case analysis. This study comprises a variety of tactics to generate meaning and move successively from the concrete evidence to a conceptual and abstract level of understanding (Miles & Huberman, 1994). The tools that were used to facilitate data analysis include computer aided qualitative data analysis software (CAQDAS) package QSR NVivo 10, as well as several MS Office applications (Excel, Visio, PowerPoint, Word). Figure 18 provides a visual representation of the analysis process, which is further outlined below.
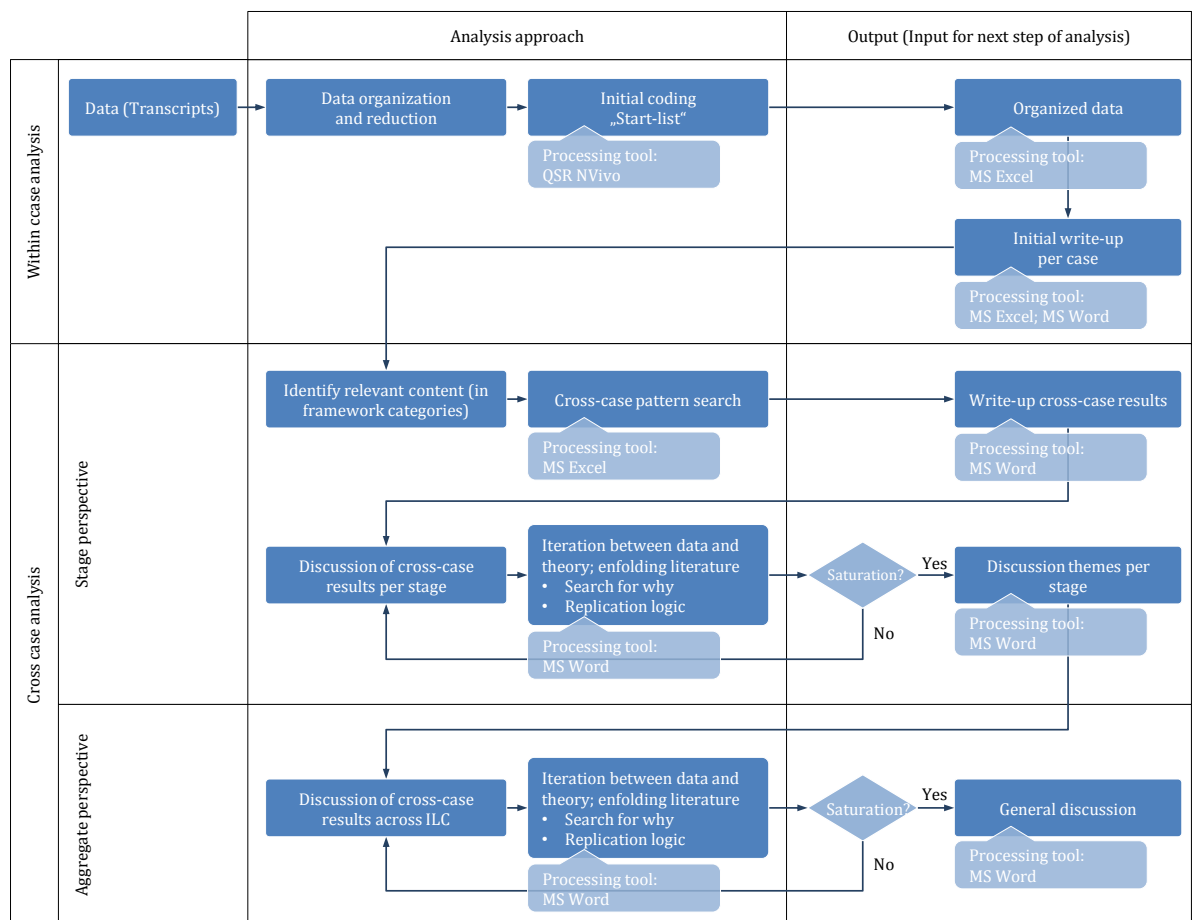
Figure 18: Analysis process

4.6.4.1   Within-case analysis

Within-case analysis refers to the separate examination of each individual case (Eisenhardt, 1989). Within-case analysis is useful during the early stages of the analysis process because it helps to organize and categorize data. Within-case analysis involves extensive narratives but only relatively little interpretation. Nevertheless, it enables a detailed understanding of the separate cases and documents the idiosyncratic dynamics of individual cases (Eisenhardt, 1989). In the present study, within-case analysis refers to the analysis of the individual lifecycle stages in each company. There is no standardized way for within-case write-ups (Eisenhardt, 1989). For the purposes of this thesis matrix-displays were used to facilitate the write-up of case narratives and provide a standardized format for cross-case comparison.

Initial coding: In the present study, within-case analysis began with initial coding. The main purpose of initial coding was to organize the data from each case according to the main categories of the research framework. Codes are meaningful labels that are assigned to textual data in order to structure it. Coding is a basic form of analysis and facilitates the structuring and categorization of a large amount of data into meaningful categories and sub-categories (cf. Saldana, 2009, p. 120: provisional coding). Categories refer to "bins" in which similar content is collected for further analysis (Miles & Huberman, 1994). In the present study categories refer to process innovation components, motivation for interaction, and openness at each stage of the innovation lifecycle. Codes and categories can result from theoretical considerations, but may also emerge during data analysis. The latter is called open coding. The problem with open coding can be an overwhelming amount of codes which becomes hard to process and may result in a lack of data reduction (Gläser & Laudel, 2013). Miles and Huberman (1994) thus recommend using a provisional start list of codes based on the conceptual framework. Initial codes help to stay focused but may have to be complemented with additional emergent codes, be revised, or be rejected as the analysis proceeds. In the present study an initial list of codes was used to categorize the empirical data according to the research framework. The initial coding-list comprised a set of codes for each framework category. The initial codes were mostly based on literature review. Additional codes emerged during the coding process. Appendix 9: Coding framework provides the list of initial and emergent codes and their description.

Matrix queries: Following the initial coding, QSR NVivo 10 was used to run matrix queries for each company. The matrix queries display the raw data coded at each framework category across the lifecycle stages developed in the initial research framework (see again section 3.5). Based on the results of the queries the content of the original data was extracted and summarized for every framework category and every emergent sub-category (cf. Gläser & Laudel, 2013, p. 6). This step facilitated data reduction and translated the data into the more analytic language of the study, thus generating a first step towards abstraction. For each

summary references to the original data sources were kept in order to maintain transparency and allow for further clarification if necessary. This process resulted in a set of very large data tables that provided an overview of the relevant content in each category, for each individual company (cf. Miles & Huberman, 1994, p. 178: "monster dogs"). The large tables enabled a structured write-up per case. This led to two forms of output: (1) case description summaries and (2) comprehensive case write-ups of circa 60,000 words. These documents were used for member checking (Stake, 1995). The comprehensive case write-ups provided a standardized format for cross-case comparison. Within-case summaries are provided in chapter 5 of this thesis to provide key insights from the individual cases.

4.6.4.2   Cross-case analysis

Cross-case analysis aims at identifying emergent patterns across cases to enforce a rigorous analysis that overcomes initial impressions (Eisenhardt, 1989; Miles & Huberman, 1994). The purpose of cross-case analysis is to overcome potential limitations to the accuracy of information generated from the data. It facilitates a stronger reasoning than an exclusive focus on individual cases and helps reducing the risk of premature or false conclusions (Eisenhardt, 1989).

Iterations of cross-case analysis: Given the objective and units of analysis in this thesis, the study comprised two main iterations of cross-case analysis. First, each lifecycle stage was analyzed and discussed individually, to emphasize the lifecycle perspective of the present study. This was necessary to account for the characteristics of each stage separately and to identify important themes within each stage. Recall that themes refer to those topics that emerge across all companies at a specific lifecycle stage and relate to one or more framework categories (process innovation, motivation, openness) at that stage. This iteration of cross-case analysis addressed the first unit of analysis (the management of open process innovation at the individual lifecycle stages). Afterwards, an aggregate perspective was adopted to document and discuss the dynamic development of the different themes across the innovation lifecycle. This iteration addressed the second unit of analysis (the management of open process innovation from an aggregate lifecycle perspective) and ultimately led to new constructs of open process innovation. The following sections provide further detail on the two iterations of cross-case analysis.

First unit of analysis (lifecycle stage perspective): Having categorized the data into structured tables, it was possible to display the results from all cases for a specific category within a particular lifecycle stage next to each other; for example: Motivation for open innovation at the adoption stage for BMW, Knorr-Bremse, Thyssen Krupp Marine Systems, ZF Friedrichshafen, and TE Connectivity (Figure 19). This structure enabled a second round of data

reduction to elicit emerging patterns (i.e. central contents) within the different framework categories (process innovation, motivation, openness) at a specific lifecycle stage and across all cases.

Figure 19: Screenshot of data analysis table
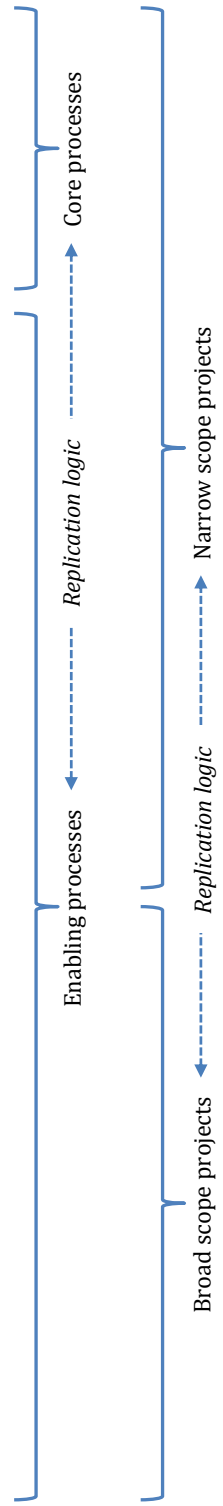
The patterns (i.e. central contents) were then identified by looking for similarities and differences across cases (cf. Eisenhardt, 1989). More specifically, the insights from the companies that reported on the development of enabling processes (BMW, Knorr-Bremse, Thyssen Krupp Marine Systems, ZF Friedrichshafen) were compared for literal replication. This means that an emergent pattern was recognized when the same insight was found in multiple cases without any explicitly contrasting evidence. At a later stage, theoretical replication was sought by contrasting these patterns with the findings from the case that reported on the development of core processes (TE Connectivity). If explicitly contrasting evidence was identified, both patterns were noted with reference to the different cases from which they were obtained. In the same manner, the cases that reported on broad scope projects (BMW; ZF Friedrichshafen) were contrasted with those reporting on narrow scope projects (Knorr-Bremse; Thyssen Krupp Marine Systems; TE Connectivity). The cross-case pattern search resulted in the identification of relevant patterns and sub-categories within each framework category at the particular lifecycle across all companies. The contents of the resulting patterns were summarized and documented in another spreadsheet, with references to the original data sources from which they were obtained. These tables enabled the cross-case write-up per lifecycle stage. Summaries of the cross-case tables are presented in the empirical chapters of the thesis.

Identfying themes at individual lifecycle stages: The cross-case patterns at each stage were then further analysed to elicit the key themes of open process innovation at that individual lifecycle stage. Themes resulted from the reflection on the linkages between the different framework categories and from explicating the role of different characteristics of the selected cases (enabling processes vs. core processes; broad scope vs. narrow scope). Miles and Huberman (1994) call this approach "pattern coding" in which organized and summarized material is pulled into "more meaningful and parsimonious units of analysis" (p.69). Furthermore, this process involved "enfolding" existing literature to confirm, contrast, or complement the empirical results of the present study and integrate them with the broader body of knowledge (cf. Eisenhardt, 1989). In addition, the emerging themes were constantly compared with the data and vice versa, in order to successively approach a theory that closely fits the data (cf. Eisenhardt, 1989). In particular quotes or excerpts from the interview data were sought for each of the emergent themes. The constructs were also critically assessed with reference to the underlying theoretical reasons as to why they exist, and the logic of their implications for the relationships between different variables to increase their validity. The analysis process only ended once saturation was reached. That is, once further iteration between theory, data, and literature, yielded no further significant changes to the themes (Eisenhardt,

1989). Moving from patterns in the different framework categories to themes across categories within the individual lifecycle stages was a further step towards abstraction and construct development.

Second unit of analysis (aggregate lifecycle perspective): To address the second unit of analysis, the themes from the individual lifecycles were aggregated and the level of abstraction increased to propose theoretical constructs of open process innovation. Abstraction was sought by explicating the general classes that the themes across the different lifecycle stages referred to (see Appendix 10) (cf. Miles & Huberman, 1994). This occurred in a highly iterative process in which emerging constructs were shaped by refining their definition and comparing it with evidence in the original data. The constructs were again critically assessed with reference to the underlying theoretical reasons as to why they exist, and the logic of their implications for the relationships between different variables to increase their validity. Furthermore, as recommended by Miles and Huberman (1994) and Eisenhardt (1989) the findings were linked to broader theoretical perspectives to add plausibility and increase the theoretical generalization of the findings. The analysis process ended once saturation was reached.

4.6.4.3   Summary and chain of evidence

The data analysis began with data reduction and filling the framework categories with content from the empirical data by using initial and emergent codes. Then themes were identified by reflecting on the linkages between the content in the different framework categories at each lifecycle stage, by explicating the role of the different case selection criteria, and by enfolding literature. From the themes in the individual stages further abstraction led to theoretical constructs across the innovation lifecycle. Abstraction involved the aggregation of themes across the innovation lifecycle and the search for evidence of the logical reasons behind the theoretical implications of the constructs. The analysis involved a constant iteration between data, emerging constructs, and the existing literature to increase the level of abstraction while also maintaining a close link to empirical evidence. Using the approach as outlined above made the large amount of data manageable. Moreover, the approach generated transparency and a detailed chain of evidence from the initial literature, to framework development, to the interview guide, to data collection, data analysis, and ultimately to the findings of the present study.

4.7   Measures for ensuring rigor in case-based research

The analytical operations in case-based research are flexible and lack common instructions for mandatory applications. The quality of case-based research is therefore largely judged by the

quality of the research design in terms of validity and reliability (McCutcheon & Meredith, 1993). To judge the quality of case-based research, different design tests and quality criteria have been suggested in the literature (Eisenhardt, 1989; Healy & Perry, 2000; McCutcheon & Meredith, 1993; Miles & Huberman, 1994; Stuart et al., 2002; Voss et al., 2002). The present thesis focuses particularly on construct validity, internal and external validity, and reliability (Table 11). The following sections elaborate on these quality criteria and how they were addressed in this thesis.

Table 11: Quality criteria for case-based research

Criterion	Description	Actions taken in present thesis
Construct / content validity	Refers to the validity of research conduct, coherency and approval of results, and consistency with existing theory	▪ Coding framework ▪ Theoretical grounding ▪ Clear construct definition ▪ Expert reviews ▪ Data triangulation ▪ Explicating chain of evidence
Internal validity	Refers to the credibility that conjectured causal relationships actually exist	▪ Cross-case analysis ▪ Replication logic ▪ Elaboration on logic behind relationships ▪ Use of tables and visuals ▪ Member checking
External validity	Refers to the extent to which findings apply to other contexts	▪ Duality criterion ▪ Increasing abstraction ▪ Cross-case analysis ▪ Use of theory
Reliability	Refers to demonstrating stability and consistency in the research process	▪ Case study protocol ▪ Case study database ▪ Peer review

Construct validity: Construct validity describes "the issue of establishing the theoretical territory that goes with the defined construct and ensuring consistency between it and other recognized constructs" (McCutcheon & Meredith, 1993, p. 245). To strengthen construct validity the present study uses a conceptual framework with a priori categories that relate to previous studies from various streams of literature ("theoretical grounding"). These categories were used to facilitate data collection and analysis, and to linking insights back to the broader body of knowledge. The main framework categories (process innovation, motivation, openness) constitute open process innovation and define the scope of this thesis research. Yet, they were not necessarily the only relevant constructs nor were they necessarily included in the final constructs.

Construct validity is closely related and often used interchangeably with **content validity**, which "concerns how the construct is measured rather than its theoretical basis… i.e. whether the operational measure corresponds well with the construct it is supposed to tap" (McCutcheon & Meredith, 1993, p. 245). To strengthen content validity, every construct throughout the study, regardless of whether it was adopted from literature or emerged from data analysis, was clearly defined. Expert reviews were conducted to challenge and improve construct definitions. To ensure that the empirical data actually described the emerging constructs, triangulation was performed to corroborate insights from multiple perspectives and different sources. To provide transparency on the analytical process, the chain of evidence (from research question to research protocol, interview guide, data analysis, etc.) was explicated by clearly outlining all steps of data collection, reduction, and analysis.

Internal validity: Internal validity describes "whether the conjectured relationships actually exist… the extent to which we can establish a causal relationship, whereby certain conditions are shown to lead to other conditions as distinguished from spurious relationships" (Stuart et al., 2002, p. 430). In other words: "Do the findings make sense?" (Miles & Huberman, 1994, p. 278). To strengthen internal validity, cross-case analysis was applied by leveraging the replication logic underlying the case selection of this study (cf. Eisenhardt, 1989). When multiple cases confirmed the same insights it enhanced confidence in the validity of the emerging constructs. If cases disconfirmed findings from prior cases an opportunity arose to revise and extend the emerging constructs. Furthermore, internal validity was increased by moving beyond the description of results towards the elaboration of the underlying reasons for the existence of specific relationships between different themes as proposed by the emergent constructs (cf. Eisenhardt, 1989). In order to emphasize and illustrate the internal coherence, extensive use of tables and visual illustrations was made throughout the empirical chapters of the analysis. The application of such tools was considered to enhance the coherency of the findings, to illustrate their underlying logic, and ultimately to increase internal validity (McCutcheon & Meredith, 1993; Miles & Huberman, 1994). Finally, the study followed the recommendation of Miles and Huberman (1994) and sought member checking from key informants in the participating case study companies. This provided an opportunity to confirm that conclusions were considered valid by the original informants.

External validity / Generalization: External validity refers to the "extent to which findings drawn from studying one group are applicable to other groups or settings" (McCutcheon & Meredith, 1993, p. 246). External validity therefore addresses the issue of how far the findings can be generalized. The fact that it is situationally grounded in empirical evidence is a particular strength of case-based research. While staying close to the empirical data improves the accuracy of the findings it may impede abstraction and thus act against generality (Ketokivi & Choi, 2014).

Pratt (2007) argues that qualitative studies are not statistically generalizable but instead the focus should be on analytical generalizability, "where data is generalized to a theory, not to a sample" (p.496). Analytical generalization suggests that the emergent constructs from case-based research are at a higher conceptual level higher than those of a specific case (Eisenhardt & Graebner, 2007; Yin, 2014). External validity is a necessary condition to meet the duality criterion which demands that "the contextual idiosyncrasy in case research must be balanced with an examination of the more general theoretical implications" (Ketokivi & Choi, 2014, p. 234). The present study followed a principle of increasing abstraction as it moved from initial concrete data to new constructs that describe the phenomenon of open process innovation beyond the context in which the data were collected. As described above, abstraction was sought through various tactics for generating meaning of translating data into analytical language, cross-case analysis, and replication logic (cf. Miles & Huberman, 1994). In addition, a comparison of findings with contrasting or confirming literature sharpened the boundaries of generalization and the level of conceptual abstraction (Barratt et al., 2011; Eisenhardt, 1989).

Reliability: Reliability describes "the extent to which a study's operations can be repeated with the same results" (Stuart et al., 2002, p. 430). Miles and Huberman (1994) point out that "the underlying issue here is whether the process of the study is consistent" (p.278). To strengthen reliability, a case study protocol and database were maintained throughout the time of study, so that all relevant material could be retrieved and the research process could be tracked (Voss et al., 2002; Yin, 2003). This included documentation of all correspondence with the case study companies, as well as the original data recordings and transcripts. In addition, the study followed the recommendations of Miles and Huberman (1994) and sought regular review of the research process from academic peers and experienced practitioners in innovation management to challenge the research process and findings.

5 Results of individual cases

The following sections summarize key insights from the different case study companies. This covers the companies' background, the type of process innovation (core/enabling) and project scope (broad/narrow) they reported on, responsibilities of the task force, the role of external partners, and the relevance of knowledge protection.

5.1 Case A: Bayerische Motoren Werke

sBayerische Motoren Werke (BMW) is one of Germany's largest industrial companies and one of the most successful manufacturers of cars and motorcycles in the world. Most notably, the BMW Group owns BMW, Mini, and Rolls-Royce, three of the strongest premium brands in the automobile industry. Orchestrated from its headquarters in Munich, Germany, the company has operations in more than 150 countries. BMW employs over 110,000 members, 100,000 of which work in the automobile business segment. The overall revenue in 2013 was 76 billion euros, with a net profit of five billion euros. Product quality, product development, and production capabilities determine the company's competitive advantage and appropriability regime. BMW aims to create products to a very high standard of aesthetics, dynamics, technology, and quality. Within the automotive manufacturing industries, the company holds a leading position in engineering, production, and innovation. BMW has a global production network with currently 28 manufacturing facilities in 13 countries. To enable growth, the company seeks cooperation and coordination between its facilities to ensure fast and flexible production and to achieve a competitive edge. To spot trends early and develop appropriate solutions, BMW also maintains research and development facilities in a variety of innovation hubs across Europe, North America, and Asia. The information that BMW provided for this study mainly relates to experiences with the innovation of corporate-wide enabling processes and the interaction with external technology experts and management consultants.

Type of process innovation: The information provided by BMW for this study largely relates to the development and implementation of higher-order enabling processes across the entire corporation. These processes use IT to coordinate and enable all organizational processes ranging from idea generation to product offer. They enable the optimization of internal operations with regard to time, effort, and output quality. Process documentation and coordination is necessary for end-to-end integration and common standards within the organization. It also helps to identify and resolve any bottlenecks in existing processes. The central process development and management function is particularly important given the size and complex organization of BMW. As one interviewee aptly stated:

> When four people build a car then you don't need specific processes. You sit down together and discuss who does what. It doesn't work that way when there are 100,000 employees. In this case you need to have it all well-defined in terms of what to do, when to do it, what the triggers for action are, and what the outcomes of these actions are [R4-I2] (Respondent4-Interview2).

The task force that contributed to this study has a very good overview and understanding of the challenges involved in the development and implementation of BMW's processes. While the information mainly related to enabling processes, the interviewees in this study pointed out several differences between the development of enabling processes and core processes.

Project scope: On the whole, the information provided for this study related to projects with a very broad scope. Such projects involve the management of different types of change (technological and organizational) across a variety of internal stakeholders from different departmental backgrounds. This requires substantial knowledge about the organizational structures, processes, and interdependencies between different functions and operations. As one interviewee explained:

> For me process innovation refers to large processes, something like how we manage our product development processes. These are complex processes … When you look at the various role descriptions and functions involved in such processes then you realize just how complex all these interactions are. In order to create process innovation that involves many different roles and functions, one must understand this complexity. I think that we as internal members of BMW understand this particularly well [R1-I2]

Role of the task force: The task force manages the mutual adaptation of technology and organization and is responsible for the systemic integration of new processes within the organization. The task force also coordinates different stakeholders involved in the development and production of a car. The following is an example of technological process innovation for product development. The development of a car takes about five to six years. During this period various departments (e.g. design, production, accounting, etc.) make countless changes to the product specification. The problem for BMW was that different departments used different tools and methods to document their changes. As a result the coordination of the product development process became highly inefficient. To solve this problem, the process innovation task force developed a standard database management tool which all departments had to use. Consolidating the expectations and requirements of the different stakeholders in relation to this new tool was a particular challenge for the task force. As the project leader recalls:

> What made the whole issue more difficult was that for each of these processes there were people in charge who had the sovereignty over their processes ... and they were not all convinced that a common approach of using this software in the same way was the right way forward for them [R1-I1].

This example also illustrates that addressing the resistance of operators to change is a key challenge for the task force. Even during the conceptual planning of new processes resistance emerges when operators fear interventions in their work performance. Against this background, it is vital that the task force convinces BMW's internal stakeholders of the new process' benefits. In this respect, interaction with key operators is important to meet their expectations and requirements. Yet, there is a risk in presenting unfinished technology or process descriptions as this may cause frustration and distrust among operators. Furthermore, the task force has to convey the complexity and consequences of process change to decision makers without going into detail about the technological implications of a new process.

External partners: External partners support BMW's process innovation efforts in several ways. In particular, technology suppliers and management consultants contribute to process innovation. Management consultants provide methods for organizational restructuring and help to manage process innovation projects. The task force engages in regular interaction with technology experts and industrial peers, for example at industrial conventions, to stay informed about technological trends and opportunities. As one interviewee described it:

> ...that is the ProSTEP club. Once a year there is a huge symposium with a few hundred people, 600, 700, people. All the suppliers, software suppliers, as well as consultants come there and give presentations. There are also professors who are working in our area. They all discuss where the journey is headed. Of course there is a lot of exchange in this context ... Ultimately, however, you will not talk about competitive topics though. But, yes, there is some interaction [R2-I2].

Performance gaps and ideas for process innovation are usually identified internally. External partners do, however, help to articulate performance gaps and support the analysis and evaluation of different potential solutions. For this purpose, the task force obtains knowledge from external technology experts. In addition, management consultants help BMW to benchmark existing processes. They provide tools for process evaluation, and expertise in project management. While internal stakeholders have a better knowledge of existing processes, expectations, requirements, and interdependencies, it can be difficult to bring these people together, especially in a large company like BMW. As one interview explained:

> [internal technology experts and operators] are not necessarily the ones with the skills to make such comparisons and use formal approaches to provide comparable

analysis and results to make a decision. Therefore, it can be very helpful to have an external partner that can support you methodologically... [R1-I2].

External technology partners assume various important roles in process development. They provide standard solutions or modify technologies to make them fit with the company's expectations and requirements. BMW uses standard technology for processes that do not directly relate to core operations. Standard solutions and modularity helps the task force to provide a more accurate estimate of the impact of change on the organization. The introduction of standard technology tools may require BMW to change existing processes and structures in order to realize the benefits of using the technology. As one interviewee explained:

> If I adopt the standard then I can simply adopt each new release and do not have to adapt my own solution all the time. In contrast, if I build a lot on top of it myself, then it will always require more effort to maintain, to support, to troubleshoot ... until you eventually lose the ability to adopt new releases of the software... From that perspective, yes, in many places we let standards influence and shape our processes [R1-I2].

BMW works closely with external experts on the modification or development of new technological solutions. External technology experts can comment on the feasibility of particular changes, technology design, etc. This is an important opportunity for the task force to learn about new technologies and the possibilities that new solutions offer. For example, the task force worked with an external technology expert to develop the database solution discussed above. Twice per week the task force and the external partner worked closely together to discuss the technological design. On the remaining three days, the external partner implemented the jointly developed design. This significantly improved the technological capabilities of the task force. During preparation, technology partners can assume responsibility for entire work packages in the development of new enabling technology. Nevertheless, BMW demands close coordination and maintains the project lead. This is necessary to ensure that the new technology fits with the internal processes and to create acceptance among internal stakeholder groups. As one interviewee further explained:

> What, in my experience, does not work is assigning an external partner to coordinate change within the organization but not accompany the partner. At least in the case of BMW ... There always has to be an internal member of the company that represents the project, who can explain and motivate others as to why we are doing the whole thing and why the support of the relevant department is required... [R2-I2].

BMW provided information on the adoption of technologies that are highly interconnected with other information systems, various user groups, and connecting different organizational

processes. This means that the mere installation of technologies is a highly laborious activity. For such tasks external technology experts provide additional capacities. It may also be necessary to involve external capacities when communicating new technologies and processes to a large number of operators. Some other tasks, however, remain internal. For example, planning and introduction, convincing internal stakeholders of organizational change in response to new technologies, and addressing resistance are critical tasks predominantly performed by the internal task force.

Knowledge sharing and protection: Generally, it is important for BMW to protect internal processes and the knowledge that they entail. Nevertheless, it is difficult for external partners to develop enabling solutions that fit with internal expectations and requirements without sufficient insight on BMW. A close and intense interaction with the external partner makes it easier to convey specific, internal expectations and requirements. This constitutes a major trade-off between knowledge sharing and protection for BMW. In addition to non-disclosure agreements, BMW has an internal principle to guide knowledge sharing on the operational level, which is called "need-to-know". This principle aims to prepare operators to understand what the external partner needs to know and what knowledge needs to be protected, while leaving sufficient flexibility for interaction with external partners.

Given that the task force informing this study is largely responsible for higher-level coordination of organizational processes, it is a general perception that processes are difficult to copy. External partners gain access to the company's knowledge that does not reveal how an entire process works or how it is integrated within the organizational context. While it is not critical to protect the steps and sequences of a specific process, it is nonetheless important for BMW to protect specific knowledge relating to the technical contents of the processes. For example BMW uses carbon fiber reinforced plastic (CFRP) for the external paneling of the i3 electrical vehicle to achieve weight reduction that counterbalances the heft of the car's battery pack. The development of CFRP involves a series of processing steps, such as forming carbon fiber into a web before the oxidation process. The carbon fiber then goes through the winding process before giant looms weave the carbon fiber into a textile form to prepare it for easy shaping. The use of CFRP for mass production was an industrial novelty and required new methods and technologies that were not available on the market. While BMW does not keep the sequences of CFRP processing a secret, yet the details of how the technologies work are highly confidential. These technologies are a central element of the company's core operations in the field of electrical vehicle manufacturing. For the development of such core technology BMW relied on exclusive inter-industrial co-creation alliances, for example with Boeing, or acquisitions to achieve an advantage over competitors in the automotive industry. As one interviewee emphasized:

> CFPR requires entirely new technology and methods where we can clearly say that we expect a competitive advantage from that… or topics that simply need to be newly developed for working with Carbon and the production of the new parts. How to process the material for example… you need looms that make the chopped strand woven fabrics … these are all topics where we are on the forefront and we do that mainly internally. We do not want that everybody else knows how to do these things. Therefore, we either do everything internally or through highly exclusive partnerships or acquisitions [R4-I2].

The interviewees provided similar insight into enabling processes. For example, the database management software that BMW uses and the way it is embedded within a broader organizational process are not confidential, but the information stored in the database, such as the cost of manufacture often is. BMW does not share such information with external partners or uses "dummy data" if necessary.

5.2 Case B: Knorr Bremse Rail Vehicle Systems

Knorr Bremse Rail Vehicle Systems is part of the Knorr Bremse Group, based in Munich, Germany, which is the world's leading manufacturer of braking systems for rail and commercial vehicles. Knorr Bremse is a global organization and has operations in over 90 locations in 27 countries within the regions of Europe, North America, South America and Asia/Australia. The company provides its customers with tried-and-tested standardized braking systems that cater to regional needs. Knorr Bremse comprises two business divisions: Rail Vehicle Systems and Commercial Vehicle Systems. The expert informants involved in this study work within the rail vehicle systems division. Knorr Bremse Rail Vehicle Systems (KNORR) is the leading manufacturer of railway braking systems used in high-speed trains, locomotives, self-powered trains, subways, and freight vehicles. The division has over 12,000 employees and in 2013 earned of 2.2 billion euro. KNORR considers innovation as the basis for its current and future success. The company makes substantial investments in research and development, totaling 253 million euro in 2013. Moreover, the company has introduced a long-term excellence initiative to harmonize its operations and management approaches across all locations and business divisions in order to create synergies. All initiatives for process innovation are bundled under the umbrella of KNORR Excellence. The main initiatives primarily involve development, production and logistical processes. KNORR accredits its competitive advantage to innovative products, high-end production facilities, and a highly skilled operating base, all of which enable the company to produce yield high quality outputs. The information that KNORR provided for this study mainly relates to IT-driven enabling process innovation in administration and production. The development and implementation of such processes is managed by a central

task force. Working with external technology experts during process development and implementation is a key responsibility of the task force. KNORR has global operations and is organized in a matrix structure. The production facilities have developed organically over the years. Each has its own management and works largely independent of the others. They are responsible for their own work organization and the acquisition of the manufacturing equipment, even when they make the same products as other facilities within the group.

Type of process innovation: The information that KNORR provided for this study mainly relates to IT-driven, enabling process innovation. Such process innovation does not directly relate to KNORR's core operations (e.g. production). Nevertheless, it is highly important to enable efficient operations throughout the entire organization. The following illustrative example relates to "production data management": In the past KNORR's decentralized production infrastructure made it difficult to relocate or expand specific production streams from one location to another. The documentation of available tools was not accessible across multiple locations or did not fit with the varying specifications across different facilities. As one interviewee explained:

> It already started with the number keys, with the processes how production data were
> managed, and so on. It was a problem that SAP was essentially the leading system
> where all the production orders were ultimately generated and it was obviously
> difficult to do that if you were using differently structured production records, other
> number keys, and so on... [R7-I1].

To address this issue, the task force currently works on a series of projects to develop and implement "production data management" tools. These tools will eventually enable information processing and deployment on tool availability and production requirements across the entire corporation. The benefit of such a solution is that machines can be equipped and configured according to product demand and tool availability. This increases efficiency through a reduction of idle times and higher load factors. Furthermore, it also enables strategic sourcing of relevant tools and equipment.

The process innovations in KNORR involve technological but also organizational change. When asked about the organizational changes that resulted from the implementation of a new production management tool, an interviewee responded:

> The organization of the people in the production facilities has changed in that in the
> past the man on the machine was the one who decided everything [relating to the
> production schedule]. Then the programming was transferred to the offices where
> everything was worked out on the computer and then send to the machine so that the

man on the shop floor was now no longer busy with programming the machine but instead only with maintaining the tools and installing them on the machine... [R7-I2].

Project scope: The scope of the task force's projects is typically narrow. The projects focus on integration IT-driven solutions with existing operations and have limited systemic impact. When asked about the role of systemic impact of process change, an interviewee explained:

> The main objective is to achieve an end-to-end systems integration for new technologies. That means that new technology is supposed to enable new processes and fit with the existing applications and systems landscape without significant disruptions of the existing system... [R8-I3].

Role of the task force: The task force develops and implements new processes based on the expectations and requirements of different internal stakeholders. It is often a challenge to consolidate divergent expectations given the strong decision making authority of the production facilities. Communication is critical to gain acceptance for change. The task force informs operators of the necessity for change, for example through information events, brochures, and leaflets. Moreover, key stakeholders provide feedback during the development of new processes to ensure that solutions meet the expectations and requirements of the operating base. When asked why this was important for process development, one interviewee replied:

> For the development of processes this is important because the people are much more willing to adopt the new processes if they feel that we focus on their expectations and requirements [R6-I1].

The task force also communicates with decision makers to obtain approval for specific solutions. A key challenge here is it to convince senior managers with an administrative background of operational requirements.

External partners: KNORR benefits from external contributions throughout the entire innovation lifecycle. The task force regularly interacts with external technology experts, such as universities, technology suppliers, or industrial peers at relevant workshops and conferences to gather ideas and maintain an overview of available technologies. During the early stages of an innovation project these efforts are intensified:

> For new ideas and the practical implementation of new ideas it is good to talk to suppliers or to go to trade fairs and workshops. If you have the resources you look around what technologies exist that could be useful [R6-I1].

If required, neutral technology experts or consultants help to evaluate potential technologies or internal expectations. Typically, KNORR's top management hires management consultants to provide expertise on broader, more fundamental changes to the company's general approaches

towards certain issues, for example organizing engineering operations on a global level. The task force does not usually work with external management consultants. The narrow project scope and internal expertise in process IT make such involvements unnecessary.

During process development and implementation the task force typically only engages with a single technology partner. KNORR obtains technology from external suppliers to enable internal processes. Nevertheless, these technologies are not necessarily "off-the-shelf". Due to KNORR's heterogeneous production infrastructure it is sometimes necessary to heavily customize external technology to make it fit with the organization. While the task force is able to configure technologies within the range of existing functions, external partners are usually necessary for the development of additional functions. The interaction with external partners enables the task force to develop new capabilities for operation and maintenance, and provide training to operators.

In contrast to technology modification, the acquisition of standard solutions can require changes to the existing processes and perhaps even to roles and responsibilities. The technological information that external partners provide, leads the task force to identify organizational changes that become possible through technological change. One interviewee explained how external information enables improved processes even though this may involve organizational change:

> ...now we always try, increasingly forcefully and with more and more confidence, to say: 'Ok these are the abstract process requirements, these could be enabled in a certain way using a new technology'. But that also includes significant changes in the process and how to work it, perhaps even organizational changes, as in changing roles and responsibilities... and then the change is implemented through what we learn from our implementation partners with regards to the optimal implementation of the new technology. If we did this without external partners we would much rather rely on our known process solutions... [R8-I1].

The implementation of process change is the domain of the internal task force. Likewise, the integration of a new process with the existing organizational system and the communication of change to the operating base are internal responsibilities. The reports by the task force members suggested that external partners lack sufficient insight into internal processes, structures, expectations, requirements, and capabilities to make adequate contributions to these domains. One interviewee explained why the task force was much better equipped to explain new processes to the operators:

> ...because we do know our people better after all and it is not only software related information that has to be transported but we have a way of answering how

something fits within our 'KNORR world', how it fits with our methods, how we want to work. An external partner does not know these things. When we have an SAP interface, we know for example how our logistic experts work with that system. The external partner does not know this … For these things we are simply stronger [than external partners]… [R5-I2].

KNORR also uses external partners to access additional, temporary capacities. The external partners are of particular importance for the installation of new technology. For example, when the new production data management system was introduced to several facilities, the computers running the software needed to be linked to the machines in the production facility. The external partner was responsible for providing the relevant expertise and technicians to perform these tasks.

Knowledge sharing and protection: When KNORR works with external technology partners during preparation, the interaction is very close and in-depth. On the one hand, the task force absorbs new technological knowledge from external partners. On the other hand it conveys internal expectations and requirements to those partners. It can be particularly challenging to communicate internal requirements, when processes or sub-processes are not explicitly documented and only exist as operating routines. One interviewee explained what this meant for the interaction with external partners:

>…if this form of explicit documentation does not exist then you can [share knowledge] only through intense cooperation. That means my team has to sit with the specialists from the vendors and implementation partners and think about 'ok if we were to make these changes in a specific way, what would happen, would the workflow still function, and could the operator still work with it in the way he or she does it today? What would need to be changed?' Typically, the answers to the emerging questions result from such dialogs… [R8-I2].

For the type of process innovation that KNORR reported on during this study, external partners typically do not gain access to confidential knowledge. As one interviewee clarified:

>…the process knowledge we leave with the implementation partner is not worth protecting because it does not relate to our core business… [R8-I2].

Confidential knowledge relates to the company's core operations, such as the design of its production technology, the programming of a machine to make products with the right quality, or product specifications such as the surface roughness of specific products. However, technology suppliers of enabling process technology do not need this information in order to develop and install the new technology. Therefore, knowledge protection is not particularly challenging. On the other hand, it may be difficult to clearly dissociate internal knowledge and

share knowledge modularly. From KNORR's perspective, restrictive knowledge sharing constrains external partners in making valuable contributions. In some cases the external partner may even be provided with remote access to internal systems in order to provide ad-hoc problem solving during and after installation. In this respect, some task force members maintained that even if the external partner were to obtain critical knowledge on a specific issue, the overall operations could still not be copied as they were specifically integrated with KNORR's organizational system. As one interviewee aptly stated:

> ... that's only a small part of a braking system and only affects one or maybe ten products. It does not reveal anything about the functions of the braking system; it does not reveal the tests for products and certainly nothing about the entire braking system... [R5-I2].

5.3 Case C: TE Connectivity

TE Connectivity (TEC) is a global corporation that operates in 150 locations and offers more than 500,000 products in five main categories, including transportation, industrial, consumer, and networks. The corporation invests strongly in R&D and innovation. The business unit that participated in the present study makes switches and connectors for the automotive industry. Such connectivity and sensor products enable critical electronic functions from power management systems and smart engine controls to active and passive safety improvement systems, and smart navigation systems. The information provided for this study mainly relates to the work performed in the company's production and process R&D facilities.

Type of process innovation: The information TEC provided for this study mainly related to research, development, and implementation of production technology. These activities directly relate to the company's core operations. TEC invests strongly in the development of innovative, high-quality products. Nevertheless, the products are relatively easy to reverse engineer and replicate. Therefore, TEC mainly competes on the basis of quality as well as very high production output and ultra-efficient production technology. The production processes run within strongly integrated manufacturing equipment (i.e. the main production steps do not require different machines but operate within a single, integrated machine). The production technology affects the quality, cost, and quantity of the final production output. It also determines the extent to which production can be automated or needs monitoring. Technological problems can lead to increasing costs as well as damage to the company's reputation. Against this background, new technology development typically involves 20-30% new technology while largely building on existing and known technology components. One interviewee gave an example:

> Laser welding had not yet been used in our company. A new product made it necessary though. At this time, however, we weren't sure if it would actually work in our production. We started it as a pilot project and slowly approached it that way. The rest of the punch machine built on the known elements, such as cutting, shaping, bending, etc. All of that was well-known. Only the laser welding was new [R19-I1].

Project scope: The information TEC provided for this study concerned projects with a narrow scope, which pertain mostly to technological change in TEC's production environment. One interviewee made this particularly clear by contrasting the development of core process technology with the implementation of standardized solutions for enabling processes:

> When I think about the implementation of SAP, then we did have a strong change in the organization. When I compare that with our projects, then we have relatively little organizational change and actually try to develop the technology and the whole project in such a way that it can be integrated within the existing organization. I would definitely say we focus on the technology [R21-I1].

Role of the task force: The informants involved in this study are part of a task force responsible for the development and implementation of processes and process technology in the areas of molding, die cutting, and assembly technology, all of which are critical aspects of electronics component manufacturing. The task force focuses mainly on technological change but is also responsible for planning potentially necessary organizational changes. For example, when TEC introduced welding into its production processes, the company had to introduce new quality assurance practices. This involved developing new quality assessment criteria and training for quality assurance champions. The task force interacts with operators to gain feedback on new developments and to provide training during the introduction of new technology. In this regard, the fact that process R&D and production facilities are co-located enables the task force to gather feedback promptly. One problem is that operators often oppose change. The task force aims to motivate operators by highlighting the advantages of change. As one interviewee recalled:

> For the laser welding we now have to weld within the machine. This gives us a leading role. We have to do that. We have to make such things clear so that the team understand that the change is necessary. If we do that they are motivated to go to work [R19-I1].

The task force also communicates with decision makers who are responsible for project authorization and granting funds. While decision makers do not need to understand technological details, it is the task force's responsibility to prove functionality and describe the business case for specific solutions, i.e. outline why it makes sense to invest in a specific solution.

The development of proprietary technology is a critical enabler of TEC's competitive advantage. The task force's main ambition is therefore to develop new technology internally. However, if external solutions are readily available these can be acquired from the market. As one interviewee put it:

> If there are partners who already have experiences with new processes and technologies, then we first buy the process technology there [R24-I2].

External partners: The information TEC provided mainly relates to proprietary core process technology. Typically the company cannot acquire solutions externally. While TEC acquires technological components from external suppliers, the development of the new equipment itself often remains an internal responsibility. Development work comprises the construction of new machines as well as the integration of different components. More specifically, this involves linking different components, wiring, software installation, configuration, and so on. The value added through integration is significant and sets TEC's process technology apart from other companies' solutions. Although the integration of technological components is an internal responsibility, external technology experts affect the development of new process technology in various ways. The task force initially scans the external environment for possible new solutions, for example through supplier visitations or trade fairs. The initial search is often very indirect or covert in order not to reveal ideas for new process technology. The new information is further developed into conceptual solutions with a more specific business case. For this purpose, TEC typically develops a few process candidates together with suppliers or research institutes in order to inform an investment decision. Early conceptual research is particularly important if no information is readily available on the market. For example, TEC wanted to use laser technology in its stamping process machines to reduce the scuffing in its machines. An initial environmental scan yielded no suitable solution or information about the feasibility of implementing laser technology components in stamping machines. Therefore, TEC sought to create such information to make a business case for the new technology. For this purpose the company worked together with the Fraunhofer Institut to assess the feasibility of the idea. This minimized the risk involved in the new solution and also provided an opportunity for TEC to access external knowledge early on. The work with research partners is limited to conceptual studies. It does often not include the full technology development. Detailed development requires access to exact processing specification and real operations. Therefore, access for external partners is deliberately restricted during these stages. While external partners develop components according to TEC's specification, the integration of these components is performed by the task force. During development and implementation, the task force aims to involve external partners only if there are very specific problems to solve. Nevertheless, limited internal capacity sometimes makes it inevitable that TEC works with external partners during the development stages. For example,

due to limited internal capacities TEC had to work with an external partner to develop a process for quick change-over. For example, a new operations excellence initiative called "TEOA" increased the company's focus on lowering inventory and scheduling production more flexibly according to demand. This made it necessary to improve operations with regard to quicker change-over for stamping machines (i.e. becoming faster at putting different tools on a machine to make different products). An external supplier could readily provide the technology to provide a modular packaging for the tools so that they could simply be changed within the machine. TEC had the capabilities but not the capacities to develop the technology internally. Therefore, TEC had to provide the partner with all process specifications that these tools performed. In return TEC benefitted from the external partner's expertise and managed to meet the targets of developing the new technology in time. However, In a production environment TEC does not typically work with external management consultants. The core processes are production processes and directly relevant to the company's core business. The task force understands internal expectations, requirements, infrastructure, capabilities, and work organization much better than external consultants.

Knowledge sharing and protection: TEC creates competitive advantage from the integration of technological components within core process technology. The technology specifications thus represent critical, confidential knowledge that TEC seeks to protect. Yet, the task force considers it impossible to contain such knowledge when there is interaction with an external partner. Generally, TEC uses legal mechanisms, such as NDAs, to protect intellectual property. The interviewees, however, expressed concerns as to the monitoring and enforcement of the protection of process related intellectual property. One interviewee pointed out that patenting processes may reveal more than it actually protects:

> In reality we often think that if one were to patent a process more of that process would be revealed than would actually be protected [R23-I1].

The task force therefore seeks to protect core process innovation by means of secrecy and strategic supplier relations. As mentioned above, the task force aims to restrict the involvement of external partners during the development of new technology. Because they only provide individual components of the whole technology, external partners gain no more than a limited glimpse of the final result. Moreover, TEC works with external partners from different industries and develops strategic, exclusive relationships with them. Typically, the company works with partners from other industries. These companies provide new knowledge. TEC trains them in exchange for exclusivity. The main purpose of this approach is to restrict the potential for the external partner to use TEC's knowledge on the market. As one interviewee put it:

> We have absolutely no problem if that partner also works for others because we know
> exactly that the others will never be our competitors. On the contrary, we can
> certainly learn from the experiences our partner has made in other sectors [R18-I2].

Nevertheless, sharing internal knowledge is critical to enable the external partner to make a contribution. It is important to have the relevant internal capabilities to manage the sharing of knowledge. Task force members have to understand what knowledge external partners require to make a contribution. For example, external partners are only provided with the construction plans for individual components of the entire machine but the specification of the entire machine is not shared with external partners. However, as indicated above, revealing confidential knowledge is sometimes inevitable when external capacities are exploited.

5.4 Case D: Thyssen Krupp Marine Systems

Thyssen Krupp Marine Systems (TKMS) is a worldwide leading manufacturer and systems-provider for non-nuclear submarines and high-level naval vessels. TKMS has its main operations in Kiel, Hamburg and Emden (Germany). Since 2005 the company is part of the ThyssenKrupp Group's business area Industrial Solutions. TKMS operates in the military defense sector, which adheres to specific government regulations. TKMS develops one-of-a-kind products that are tailored towards the specific requirements of individual customers (i.e. prototype production). In the past, the company's sole focus was on product differentiation. As one interviewee remembered:

> We are in the defense sector. Up until recently we were able to bring a product to
> market, no matter the costs, simply because of the quality of the product, because it
> has a technological advantage compared to our competitors. In this regard we have
> clear quality advantages and differences in quality compared to others that we could
> sell to almost any price [R12-I1].

More recently, in light of growing international competition, decreasing defense budgets, and increasing customer interest in process specifications, TKMS has strengthened its focus on process innovation. The company is characterized by a very difficult business model. Prototype production is highly complex due to the vast amount of information processing necessary to build a submarine to customer requirements. TKMS submarines comprise 300 million components. The overall lead time from the initial order to delivery can reach up to seven years. It is difficult to construct a submarine precisely prior to production and often changes have to be made at the customer's request while the ship is being built.

Type of process innovation: The information TKMS provided for this study mainly relates to

the development and implementation of IT-driven enabling processes within the company's production environment. In addition, interviewees reported their experiences relating to organizational process innovation, and process technology research. TKMS production currently remains traditional. It is based on skilled manual labor rather than automated processes and robotic support. Nevertheless, TKMS has started investing in research on advanced production and manufacturing technologies. The following sections provide an example of such research. In this project TKMS works with inter-industrial partners to explore the possibilities of laser-scanning and mixed-reality technologies for multi-material component adjustment processes, as outlined in the following.

Various parts of the submarine include steel and glass-fiber reinforced plastic (GFRP) components. Assembling these components requires that both match each other in shape and contour, as specified in the engineering drawing. During production, the components are exposed to different temperatures and operations (e.g. welding and grinding), which cause shrinking and deformation. These effects differ for different materials. The components therefore typically do not match when they are first assembled. In consequence, the GFRP component has to be adjusted. This has to be repeated several times and involves transportation across the facility, blocking other work processes. To harmonize the concurrent production of steel and GFRP components, TKMS carries out research on the use of laser scanning technology. Lasers could measure the steel components while they are made in order to create real data-based models of the steel components. This model could project the relevant measurements onto the GFRP components to indicate where more or less material is needed. This would allow TKMS to shape steel and GFRP components simultaneously and make iterative changes and time-consuming logistics obsolete.

Project scope: Most of the information TKMS provided for this study related to the development and implementation of IT-driven enabling processes in the company's production environment. The following is an illustrative example of such process innovation:

Mechanical components production is a central function in the production of a submarine. It makes and delivers mechanical components to various other areas of production. In the past it was very time-consuming to manage the production schedule, as there was no IT-enabled support to document orders and finished components. To achieve more transparency and adhere to time-limits and production schedules, TKMS implemented an IT-enabled system for the documentation and deployment of important information, such as order and inventory numbers, as well as available work capacity. The system enabled operators to track the time that had already been worked on a specific component in "real-time". The increased accuracy and transparency facilitated better production planning and efficient component distribution

processes. Without the system, the same tasks took significantly more time. The system thus enabled not only more accurate planning and scheduling but also freed up capacity to focus on production tasks. TKMS acquired the enabling software technology from an external supplier. The technology was modified to fit with the internal expectations and requirements. For example, software interfaces were developed to ensure compatibility with TKMS' SAP landscape, and different user authorization categories were introduced, to enable operators to enter but not manipulate data. Moreover, the expectation was that the new technology would be as tangible and user-friendly as possible. Therefore, the software was extended to work with touchscreen panels and accept input from barcode scanners. The introduction of the system also changed the working processes of the operators, as they had to use the system to keep a record of their work performance. Although the process innovation occurred within core operations (production), it did not change the production as such. Instead, it enabled better work organization within the production department. The project had a narrow scope and related to a single function in the company's operational core. As one interviewee aptly summarized:

> This project was not driven by the accounting department it was all about the shop floor. The fact that others benefitted from it as well was neither deliberately considered during the time of the project nor was it included in the post project evaluations. It was really a very narrow approach. We only considered the impact and effect on the production and the shop floor [R13-I1].

Role of the task force: The task force manages the development and implementation of technological and organizational change. Generally, there is a tendency for technological rather than organizational change at TKMS. The interviewees involved in this study repeatedly emphasized that the company's processes and structures had evolved over time and were deeply embedded in the operators' routines, which made it difficult to change them. Organizational changes at TKMS always trigger confrontation within the company. Motivating and convincing internal stakeholders of the need for change is a particular challenge. To overcome resistance against change, support from senior management is required as well as communication with the operators. Against this background, the task force gathers internal expectations from and communicates solutions to decision makers and operators. For example, when TKMS introduced the new IT-system to support the scheduling of mechanical components production, it was a major problem to convince operators that were used to traditional workshop-style production to reflect on their work at an abstract level and to use IT to do so. Moreover, the task force manages the interaction with external partners. This is particularly vital because due to its military status TKMS needs to be meticulous about data protection.

External partners: TKMS draws on external technology to advance its internal process innovation efforts. Early on, the task force gathers general information from external experts to

map out available solutions. For the introduction of the production scheduling system as described above, TKMS worked with the University of Applied Sciences in Kiel to scan the market and identify technologies and suppliers. Afterwards, the task force typically seeks more specific information from potential suppliers. The task force knows which type of data the technology would need to process and what main functions are expected from the technology. Nevertheless, the presentations by external partners are extremely important to generate an understanding among the task force, as to which technology would be most suitable for the organization, and the expectations, requirements, and capabilities of the operators. The supplier can also provide support for technology modification and help the task force understand the technology. As one interviewee recalled the interaction with the software supplier in a typical project:

> ...back then it was actually a very good discussion from the very beginning on, that to some extent the supplier argued against our plans in order not to completely bend the system but also to find a middle way [between technological and organizational change] [R13-I2].

This provided the task force with the relevant knowledge to understand what changes needed to be made to accommodate the new technology. Moreover, working with the external partner helped the task force to develop the capabilities to train operators and maintain the technology internally. This was particularly important because it was difficult to grant external partners access to internal systems due to the company's military status.

In several interviews, external management consultants were mentioned as external partners for process innovation supporting the documentation of existing processes. At the same time, the interviewees suggested that consultants were often not very well accepted and did not gain the same access to people or did not understand the company's operations. As one interviewee stated:

> The amount of information involved in building a submarine is gigantic. This cannot be pressed into a method or tool that was developed for a different business model [R16-I1].

The same interviewee further explained why TKMS started its own process development task force.

> Ten years ago our company decided to establish an internal process development team for the very simple reason that we experienced it again and again that when consultants came to us we first had to explain our business model to them…. And it's not a simple business model … A lot of time was lost on that... That's why it was necessary to form our own internal consultancy, the process development team.

> External consultants can still provide the methods but they are always working with
> us [R16-I1].

Knowledge sharing and protection: It is a challenge for TKMS to balance knowledge sharing and protection. Because of its military status, the company has to comply with government regulations on data protection. The most important data relates to the product (submarine) itself. Access to product related data, either through access to the production facilities or IT systems is restricted. For enabling processes, as described above, the external partner does not typically require any data to carry out technological adjustments. When the external partner installs a new technology, an internal member of the task force has to monitor the work. This re-emphasizes that it is important for the task force to understand the technology well enough to maintain it independently of external partners in order to avoid having to provide external partners with access to the internal servers. Nevertheless, close interaction with external partners for process innovation is necessary because the operators in TKMS do not perform all processes as documented. Work routines evolve over time but are not always documented accordingly. It therefore takes considerable amounts of time to understand absorb the tacitness involved in the TKMS process landscape. Because outsiders often do not appreciate the complexity of the organization involved in building a submarine, it is necessary to give external partners an impression of TKMS' work. As one interviewee explained:

> The only thing that really helps is taking them by the hand and show them the entire
> dock yard. One has to take them through the shop floor to show them how complex
> this system of a submarine is, the so called underwater city of 60 meters, only then the
> people start to understand that we don't deal with simple issues. And then we get
> them to work accordingly [R16-I2].

This emphasizes the important role of the internal task force in working with external partners. The internal task force can either try to describe the internal expectations and requirements to an external partner, or aim to learn from external actors and then apply the new knowledge internally.

5.5 Case E: ZF Friedrichshafen

ZF Friedrichshafen (ZF) is a global leader in automotive driveline and chassis technology. ZF comprises 122 production companies in 26 countries. ZF offers a broad product range in the cars and commercial vehicle industries, including for example transmission and steering systems, as well as chassis components, and complete axle systems. ZF is among the top ten of the world's largest automotive suppliers, with total revenues of about 17 billion euro in 2013 and over 72,000 employees. Organized in a matrix structure, ZF's business units are assigned to

four main divisions: Car Powertrain Technology, Car Chassis Technology, Commercial Vehicle Technology, and Industrial Technology. As a result of a series of acquisitions over time the process landscape across the "companies" in ZF's global operations network is very heterogeneous. The different divisions and production facilities have very different cultures, and strong decision making authority, as well as different expectations, and requirements of technological and organizational change. ZF believes in innovation to maintain a dominant position within its industries. The company therefore makes substantial investments in research and development. In 2013, it invested 954 million euro in research and development. In order to advance process innovation ZF works with external partners such as technology suppliers and management consultants.

Type of process innovation: For the present study, ZF mainly reported on the development and implementation of higher-level enabling processes. These processes facilitate the management of product and production related data across the entire value chain and all divisions within the ZF group. They are critical enablers and connectors of the different work activities throughout the product lifecycle. The following description illustrates such processes in more detail.

Product data is important for the work activity of every central business unit. Development describes the different components of the product, procurement requires the data to acquire the relevant components, production is responsible for assembling the different components, and so on. The object list, a central repository where the relevant product data are stored, is critical for work performance in the different business units. Deploying the object list in the different units seems trivial when referring to operations in a single location but it becomes a major challenge when operations are distributed across a heterogeneous global operations network, as in the case of ZF. Consider the example of production. ZF makes the same products at different locations each of which adheres to the same product description and quality standards. Due to historical development, however, the locations have their own processes, suppliers, machines, operator competencies, and so on. Treating each location as an independent entity and the products they make as different products, although they are actually the same, impedes the realization of synergies between the different units and locations. Such synergies include, for example, improved procurement conditions through large batch orders, higher load factors through better use of available tools, automated production, or less administrative and development effort through the use of centrally provided and automatically adapted object lists. To achieve such synergies ZF engages in a variety of innovation projects. The task force develops corporate processes and tools that allow the company to collect product and production data from the different business units and heterogeneous production facilities, and then to harmonize it, and deploy it across the organization. Moreover, the task force provides support for the

different locations and different functions to adapt their own processes to fit with the new overall process, for example in terms of how to store and retrieve production related data.

Project scope: The type of process innovation that ZF described for this study requires the coordination of technological and organizational change across the entire organizational system and needs to account for interests across all divisions and business units. As such the projects are very broad in scope. There is a general preference in ZF for achieving process innovation through technology introduction rather than organizational change. Nevertheless, organizational change is often necessary, especially when implementing standard technology solutions such as SAP. Implementing such changes can create fierce resistance among the different locations and divisions, each of which has authority to make their own decisions and have their own work organization, cultures, and expectations of technology and organization.

The role of the task force: The task force develops and implements the technologies to document, manage, and deploy product and production data to ensure the data availability and integrate operations across ZF's global network. In doing so, the task force provides guiding instructions for the development of sub-processes within each function and works with the developers of such processes to adjust new processes to the corporate standard. The task force has a unique understanding of the global operations, divisions, functions, and the potential synergies that can be created. As one interviewee put it:

> ...we as a central department know both the requirements of the various departments and for each area individually, as well as across all areas, but also the technical possibilities of developing the relevant IT. That is, we are actually in the best position to identify synergies, and to achieve harmonization and standardization, and therefore processes for the corporation to become more effective and course also to become more successful [R32-I2].

The task force interacts with different organizational stakeholders during the development and implementation of new processes. In ZF successful process implementation requires bottom-up acceptance by operators. As a result, the task force (together with the internal IT department) gathers expectations and requirements from operators in different business units and divisions to plan, develop, and implement new enabling technologies and to address uncertainties relating to organizational change. At the same time, the task force has to communicate and agree upon development work with divisional and corporate decision makers. The task force is also responsible for managing the interaction with external partners.

External partners: External partners are important for ZF throughout the entire process innovation lifecycle. They provide management tools, as well as expertise and technology for technological change. The task force engages in continuous environmental scanning to identify

relevant new technology. This involves for example, exchange with universities, memberships in industrial consortia, attendance at trade fairs, and exchange with strategic suppliers. These efforts are intensified when necessary to identify potential solutions for a particular performance gap. For the type of process innovation ZF discussed in this study, the company leverages externally developed technology. External technology experts are therefore important throughout the entire development process. Prior to making an investment decision, for example, technology suppliers present their solutions according to a variety of criteria (i.e. use case scenarios) provided by the task force. This helps the task force understand potential solutions in more detail and compare alternatives. One interviewee explained how this works:

> ...it was relatively straight forward. We provided the suppliers with a catalogue with scenarios and processes from 80 topic areas and a questionnaire with 300 questions from the IT department. The suppliers had to work through the questions and explain which solutions they could offer to enable our processes. We have now reviewed and evaluated the presentations and try to decide how suitable the different suppliers are for us and how to proceed from there [R28-I2].

Once ZF decides on a supplier, this partner helps the task force to adapt and install the technology. The external partner can provide information on certain issues, such as technological adaptability, and hint at necessary organizational requirements. Nevertheless, translating this information to the internal context of the company is a key responsibility of the task force. During preparation of new processes the task force interacts intensely with the external partner to develop the abilities to maintain the technology independently. As one interviewee explained:

> The goal is when we have a new software to get the internal IT department to be able to maintain the technology independently so that we can be relatively flexible and do not always have to consult an external partner [R28-I2].

Although it was not the main focus of the information that ZF provided for this study, it was repeatedly pointed out that when developing new core process technology, the company prefers to detach from external partners early on to maintain exclusive access to the new technology.

Management consultants often support the task force in process development through methodological guidance during the early lifecycle stages. The task force is responsible for standardizing and coordinating processes across the entire corporation. The methods that external consultants provide help the task force cope with the variety of processes, and interests, interdependencies, and issues in the technological and organizational domain, and to achieve transparency. For example, ZF worked together with IBM's management consultants to obtain a method for aggregating, documenting, displaying, and evaluating a large set of

information the task force had gathered on ZF's internal processes. Leveraging the external knowledge advances ZF's process development efforts by creating a basis on which to develop new processes and project plans. While management consultants are important to provide methods and to help benchmark existing processes, their acceptance among the operators is limited. It was repeatedly mentioned in the interviews with the task force in ZF that external drivers for change, especially organizational change, are often rejected by the operators who believe that "outsiders" do not understand the day-to-day routines by which the company operates. Planning and communication of organizational change is therefore an internal responsibility.

Knowledge sharing and protection: While knowledge protection is very important for ZF, the company's heterogeneous process landscape makes providing external partners with sufficient information to enable their contributions unavoidable. As one interviewee explained, when asked about the main problems of working with external partners for process innovation:

> ...this heterogeneity ... that we have within ZF, you first have to understand that if you want to provide some form of meaningful consultation. You first have to get to know ZF. What products do we have? How do the processes work? Who is involved in the processes? In a company like ZF this can require quite significant effort. We first have to teach them... [R28-I2].

The task force has to convey internal expectations and requirements to the external partner. This is necessary to enable external contributions and determine whether the new technology fits or can be adapted to the existing organization and technological infrastructure. ZF deploys use case scenarios to communicate expectations and requirements to potential technology suppliers early on. Moreover, several interviewees considered it important to involve management consultants in internal meetings, so that they understand ZF's expectations and requirements, and can support method application, and answer further questions.

During technology development or modification, the supplier requires sufficient information to understand the purpose and sequence of a new process. While external partners contribute to technology change, knowledge protection is particularly important when product or production related information is concerned. More specifically, this includes product descriptions and the production details. In addition to NDAs, ZF takes various measures to protect this information. Typically, external developers do not require access to the data that enabling technologies process. The technology is developed in a shielded development environment, until it can be installed and configured. ZF is keen on developing internal competencies for technology configuration and maintenance in order to avoid granting external partners access to internal systems once a new process is in operation and processing confidential data. If technology

suppliers require sample data during development work, these data are "dummified" in order to prevent knowledge leakage, e.g. product related data of products not yet on the market or production specifications of proprietary manufacturing equipment. Finally, several interviewees emphasized that the overall integration of a process was important to appropriation. As one interviewee aptly stated:

> For the entire, integrated process we will certainly not reveal everything because there is know-how involved. When we spoke of product and document know-how in the past, we now speak of process know-how. We know we have advantages over our competitors and we try to keep these things to ourselves. Therefore, one will hardly reveal the entire process [R29-I1].

Table 12 provides an overview of the key insights from the different cases.

Table 12: Summary case results

	BMW	KNORR	TEC	TKMS	ZF
Background	Global car manufacturer in the high priced luxury segment	World's leading manufacturer of braking systems for rail and commercial vehicles	Global electronics company that produces switches and connectors for the automotive industry	Global leader in non-nuclear submarines and high-level naval vessels	Major global supplier of automotive driveline and chassis technology
Type of process	**Enabling** Higher-order processes to enable and coordinate all organizational processes from idea generation to product offer	**Enabling** IT-driven, enabling process innovation within development and production in railway division	**Core** Production technology and processes directly related to core operations	**Enabling** IT-driven enabling processes within the company's production department	**Enabling** Higher-order enabling processes to facilitate the management of product and production related data
Project scope	**Broad** Coordination of process innovation across various internal stakeholders and entire corporation	**Narrow** Process innovation within individual departments and limited systemic impact	**Narrow** Mainly technological change in production environment	**Narrow** Process innovation within individual departments and limited systemic impact	**Broad** Coordination of process innovation across various internal stakeholders and entire corporation

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	BMW	KNORR	TEC	TKMS	ZF
Role of the task force	Managing mutual adaptation, technological, and organizational change, as well as systemic integration Provide guiding instructions for the development of sub-processes within each function Coordinating different stakeholder perspectives Managing interaction with external partners	Managing mutual adaptation, technological, and organizational change, as well as systemic integration Coordinating different stakeholder perspectives Managing interaction with external partners	Managing technological change and systemic integration of new technology and minor focus on organizational change management Coordinating different stakeholder perspectives Managing interaction with external partners	Managing mutual adaptation, technological, and organizational change, as well as systemic integration Coordinating of different stakeholder perspectives Managing interaction with external partners	Managing mutual adaptation, technological, and organizational change, as well as systemic integration Provide guiding instructions for the development of sub-processes within each function Coordinating different stakeholder perspectives Managing interaction with external partners
External partners	Help articulate performance gaps and provide tools for process evaluation Provide ideas and overview of available technologies Provide standard technology and modification Comment on feasibility of technological change Additional capacities during installation	Provide ideas and overview of available technologies Provide standard technology and modification Comment on feasibility of particular changes Additional capacities during installation	Provide ideas and overview of available technologies Help develop process candidates (limited to conceptual studies) Source of technological components (full development remains internal) Additional capacity for technology installation if necessary	Provide ideas and overview of available technologies Provide standard technology and modification Comment on feasibility of particular changes Additional capacities during installation	Help articulate performance gaps and provide tools for process evaluation Provide ideas and overview of available technologies Provide standard technology and modification Comment on feasibility of technological change Additional capacities during installation

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	BMW	KNORR	TEC	TKMS	ZF
Knowledge sharing and protection	Convey structural knowledge (know-what) to external partner Protect specific knowledge (know-how) in form of product and production related data Critical data often not necessary during collaboration for enabling processes Restricted access to internal systems once a new process is in operation	Convey structural knowledge (know-what) to external partner Protect specific knowledge (know-how) in form of product and production related data Critical data often not necessary during collaboration for enabling processes	Technology specifications represent critical, confidential knowledge Sharing internal knowledge is critical to enable the external partner to make a contribution. Protect core process innovation by means of legal agreements, secrecy, limited collaboration, and strategic supplier relations.	Convey structural knowledge (know-what) to external partner Protect specific knowledge (know-how) in form of product and production related data Critical data often not necessary during collaboration for enabling processes Restricted access to internal systems once a new process is in operation	Convey structural knowledge (know-what) to external partner Protect specific knowledge (know-how) in form of product and production related data Critical data often not necessary during collaboration for enabling processes Restricted access to internal systems once a new process is in operation

6 Cross-case results at different stages of the innovation lifecycle

This chapter presents the descriptive results within each framework category (process innovation components, motivation for interaction, openness) as well as an analytical discussion to elicit the themes that emerged across these categories at each lifecycle stage.

6.1 Lifecycle stage 1 – Ideation: Results

6.1.1 Framework category 1: Process innovation components (PIC)

Table 13 provides an overview of the emerging sub-categories relating to the process innovation components during the ideation stage, their content, and references to the cases from which relevant evidence was drawn. The following sections outline these contents in more detail.

Table 13: Category: Process innovation components (PIC) - Ideation

Sub-category	Content	Case reference
PIC-1.1: Mutual adaptation for process description and evaluation	Theoretical overview of misalignments between potential new technology and existing organization enables early estimations and pre-selection of ideas	ALL
	Preference for developing or modifying new technology to fit with existing organization	ALL
	Process standardization and adoption of standard solutions emphasizes focus on technological and organizational change	BMW; KNORR; TKMS; ZF
PIC-1.2: Technological change as identification and pre-selection of new technologies	Expected effort of achieving compatibility as main criterion for technology evaluation and pre-selection (different definitions of compatibility)	ALL
	Estimation of relative advantage, compatibility, and complexity suffices	BMW; KNORR; TKMS; ZF
	Relatively precise specification of advantage and compatibility early on, in order to justify further investigation	TEC
PIC-1.3: Existing organization as a reference framework	Initially minor focus on organizational change and preference for maintaining the organizational status quo	ALL
	Early specification of organizational change is difficult and preferably avoided due to various factors	BMW; KNORR; ZF
	Existing structures, processes, skills etc. are determine the context in which task forces evaluate potential new technologies and develop new processes	ALL

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Table 13: Category: Process innovation components (PIC) - Ideation

Sub-category	Content	Case reference
PIC-1.4: Difficulties of systemic impact assessment	Systemic impact estimation is important to describe and evaluate a potential new solution	BMW; KNORR; ZF; TEC
	Limited time, specification, and documentation of existing processes make it difficult to articulate the systemic impact	ALL
	Operator feedback from is important for impact estimation	BMW; KNORR; ZF; TEC

PIC-1.1: Mutual adaptation for process description and evaluation: All companies considered it important to gain an early idea of the necessary adaptation involved in potential solutions. This referred to outlining a theoretical overview of the misalignments between potential new technologies and existing organizational processes, structures, technological infrastructure, and operator skills. This overview lets task forces estimate costs, time, and effort necessary to develop and implement a particular solution, as well as to evaluate its potential systemic impact. Based on such reference values the task forces eliminate process candidates that do not seem to fit with the company. As far as the initial pre-selection was concerned, all task forces suggested a general preference for solutions involving more technological than organizational change. TEC in particular accentuated this position. *"At the beginning, when we propose new projects, we do not talk about organizational changes"[Respondent21-Interview1].* The task forces in BMW, KNORR, TKMS, and ZF, however, reported approaches such as "*first consider[ing] what we want to do in terms of technological change. Then we assess what this means in terms of what we have to do on the organizational side*" *[R2-I1].* Highlighting the particular case of enabling process development, the interviewees in these cases explained that *"when adopting standard solutions, we have to accept that there will be costs and organizational changes that are absolutely necessary. By adopting standard solutions, however, we can just join in on every new release and do not have to adjust the technology over and over again" [R1-I2].*

PIC-1.2: Technological change as identification and pre-selection of new technologies: During ideation managing technological change refers to the task forces' search for potential new technologies. All companies reported that the anticipated effort of achieving compatibility was the most important criteria for technology pre-selection. *"In a company like ZF we cannot simply install something new. There must be appropriate interfaces between new and old technology, the new technology must be adaptable. We try to assess the chances of a new technology actually being implemented relatively early on" [R27-I2].* Similarly an interviewee in BMW stated that: *"If you notice at a fairly late stage that a technology does not fit with BMW, all the inter-dependencies may make it very costly to change everything all over again. We have to*

account for the costs and effort of such change. Therefore, we aim to consider adaptability and potential fit relatively early during the idea generation stage" [R3-I1]. Likewise, Knorr highlighted the relevance of potential compatibility when selecting new technologies: *"We looked at several systems. Because we are talking about standard solutions, there are a lot of them available on the market. We mainly looked at how flexible and adaptable the solutions were to our specific requirements" [R7-I1].* According to the reports compatibility can refer to the fit of potential new technology with expectations of new technology, the existing technological infrastructure and systems landscape, corporate strategy, and existing operator skills and sophistication. The task forces further reported that technology uncertainty was the main challenge during early technology assessment. During ideation, potential new technology is not yet acquired or developed. As a result observability and communicability remain low. This makes it difficult to evaluate new technology with regard to relative advantage, compatibility, and complexity. Therefore, the task forces in BMW, KNORR, TKMS, and ZF frequently stated that a rough estimate of such attributes was sufficient during ideation and that *"the general expectations are clear, but we have nothing defined in terms of how exactly the process is supposed to work" [R13-I1].* TEC, in contrast, suggested that in order to justify further investigation of core technology, the relative advantage needed to be specified quite precisely early on. In particular a TEC interviewee stated that *"you have to think about the product, you have to look at the design and understand the critical aspects of the product and what the implications for the design of the process are" [R23-I1].* Against this background, TEC adopts the following approach: *"When we develop new core technology, 70-80% of it is proven elements and components. We accept that there is a risk with the remaining 20-30% that is completely new to us. We do not know if the technology really works as we expect it to do, but this way we do not stray too far from what we know" [R19-I1].*

PIC-1.3: Existing organization as reference framework: The task force reports in the present study show that organizational change can relate to organizational structures, existing processes, and operator skills. While organizational change is often necessary for the implementation of industrial standard solutions, BMW, KNORR, and ZF stated that it was difficult to estimate organizational change early on. One ZF interviewee explained that: *"When a new technology is introduced the organizational impact has to be investigated. To do that you have to understand the new process as well as the interdependencies and the requirements of the different organizational units affected by it. This is difficult to identify in detail right at the beginning, when the solution is not yet clearly defined" [R26-I1].* The reports across all companies further suggested that the task forces typically used existing organizational structures and processes as a "reference framework" for evaluating potential new technologies and developing new processes. One interviewee answered the following when asked to what extent

organizational changes were considered during ideation: *"The organization provides a constraining frame that we cannot ignore. The organization is what we already know. We must understand how our company is structured. I have to know the dependencies, the objectives, the structure within the decentralized organization and the responsibilities and decision making authorities of the individual business units. These determinants provide frame within which the processes must be developed, optimized, and implemented" [R29-I1].* TEC in particular stressed this point by suggesting that the main priority during ideation was to develop concepts for new core process technology by clearly *"... describing what we expect, what degree of machine capacity utilization we expect, define the machine capabilities and whether the new technology fits with the existing processes and operation" [R23-I1].*

PIC-1.4: Difficulties of systemic impact assessment: All task forces claimed that systemic impact assessment was a major challenge during ideation. According to the task force reports systemic impact referred to the assessment of organizational or technological changes beyond the immediate locus of process introduction that might be necessary to enable new process introduction. BMW, KNORR, ZF, and TEC stated that systemic impact should be considered when describing and evaluating process candidates. As with organizational change, company size and vague specifications make it difficult to understand systemic impact, especially in broad scope projects (BMW; ZF). Furthermore, poor process documentation impedes systemic impact assessment. BMW, KNORR, TKMS, and ZF all reported that operators in different locations often changed their processes without documentation and *"old solutions are often heavily customized. If we push a button somewhere, we do not know what happens at the other locations and other divisions. It is difficult and requires an immense effort to identify such interdependencies. That is what can make projects highly complex and often it is not feasible or possible to identify all systemic impact early on" [R30-I1].* Existing processes thus involve substantial amounts of tacit experience-based knowledge. This creates a problem, as task forces do not understand existing processes in detail. To address this issue *"the people who operate these processes on a daily basis and actually experience the operations ... can help generate an initial idea of the broader impact and the interdependencies in such a project" [R1-I1].*

6.1.2 Framework category 2: Motivation for interaction with external partners (MOT)

Table 14 provides an overview of the sub-categories relating to the motivation for interaction during the ideation stage as well as their content and references to the cases from which relevant evidence was drawn. The following sections outline these contents in more detail.

Table 14: Category: Motivation (MOT) - Ideation

Sub-category	Content	Case reference
MOT-1.1: Gathering information on available technologies to fertilize ideas	Initial interaction with various technology experts to gather general information and fertilize ideas	ALL
	Early specification of solutions makes it necessary to gather very specific information from only a few technology experts early on (typically the case for production technology development)	TEC; (ZF)*
MOT-1.2: Obtaining methodological guidance	Management consultants provide innovative methods and additional capacity for scoping performance gaps and project planning	BMW; ZF
	Management consultants explicitly not involved in context of projects with limited scope and focus on core operations	KNORR; TKMS; TEC

ZF provided additional, corroborating evidence for this content

MOT-1.1: Gathering information on available technologies to fertilize ideas: The companies reporting on the development of enabling processes (BMW, ZF, TKMS, and KNORR) stated to interact with various external technology experts during ideation. *"Well, at the beginning, when we have to be creative, we actually really use every input we can get to generate ideas" [R28-I2]* and *"to get an impression of what is available out there" [R27-I2].* BMW reported similar experiences when attending industrial conferences. TKMS also explained that it worked with universities and gathered information from technology suppliers. A common thread to all reports was that the purpose of interaction at this stage is unspecific and mainly serves the purpose of general information gathering to fertilize ideas. TEC, however, stated that ideas for core process technology had to be specified early on. Although, they initially search the market for available information but clarified that *"We cannot purchase standard equipment because our technology is strongly adapted to our facilities and our products. There are various technology suppliers. With their systems, we would not be as strong in the market, as we are. Therefore, we develop core technologies in-house" [R22-I1].* TEC therefore tries to generate specific information through interaction with a few selected technology experts (research institute or known supplier). Explaining a typical case a TEC interviewee stated: *"we contacted a Fraunhofer Institute and began initial discussions. The next step was it to develop this concept in a bit more detail to demonstrate the general feasibility of the technology and identify its basic parameters" [R24-I2].*

MOT-1.2: Obtaining methodological guidance: BMW and ZF suggested that management consultants were important external partners during ideation. *"We work with external management consultants, for example, for analyses. We may have several issues but not sufficient*

capacities to investigate them in more detail. [Consultants] then analyze them and provide an evaluation, and perhaps make suggestions for improvement" [R27-I2]. Similarly an interviewee in BMW stated that*: "it is definitely possible that we have an external partner involved from the very beginning to support us with a particular methodology that we can use to analyze our complex processes and inter-organizational relationships" [R2-I2].* Reporting on more narrowly scoped process innovation projects, KNORR and TKMS suggested that they usually do not work with management consultants. *"If we are already optimally positioned [as a task force], then we do not need any external consultants. For small, narrow scoped IT projects we usually have a good understanding of all relevant issues, which is why we work without management consultants" [R8-I2].* Similarly, the reports by TEC revealed that management consultants were explicitly not involved during ideation. The task force members at TEC were certain about their superior internal expertise in technology development and knowledge about work organization at the production facilities. An interviewee explicitly explained: *"We develop core processes, production processes internally because the process know-how is critical to our financial success, it is our core capital" [R18-I2].*

6.1.3 Framework category 3: Openness during ideation (OPN)

Table 15 displays the content relating to the emergent sub-categories of openness during the ideation stage and references to the cases from which evidence was drawn. The following sections outline these contents in more detail.

Table 15: Category: Openness (OPN) – Ideation

Sub-category	Content	Case reference
OPN-1.1: Weak interaction with technology experts	No significant commitment or collaboration during interaction with technology experts; no in-depth information exchange is necessary	BMW; KNORR; TKMS; ZF
	No provision of specific information necessary when gathering general information	BMW; KNORR; TKMS; ZF
	No particular concern for knowledge protection during for general information exchange	BMW; KNORR; TKMS; ZF
OPN-1.2: More specific interaction with technology experts	Additional and more specific interaction with external technology experts for early feasibility studies, typically in case of new production technology development	TEC; (TKMS; ZF)*
	Internal knowledge needs to be shared to some extent when more specific information is gathered for technology development	TEC
	Interacting primarily with a limited number of known and trusted partners when more specific information exchange is concerned	TEC

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Table 15: Category: Openness (OPN) – Ideation

Sub-category	Content	Case reference
OPN-1.3: Frequent and in-depth interaction with consultants	High frequency, colocation, collaboration, and sharing of internal knowledge with management consultants for methods transfer and application support	BMW; ZF
	Sharing of structural knowledge is not considered an issue. Emphasis on experience and expertise of external consultants	BMW; ZF

*TKMS and ZF provided additional, corroborating evidence for this content

OPN-1.1: Weak interaction with technology experts: The task forces across all companies reported that interaction with technology experts could occur serendipitously, for example, at trade fairs or meetings of industrial consortia, but also deliberately by addressing specific external experts, such as equipment suppliers, software vendors, research institutes, or universities. The task forces usually have an idea of the type of technology that could be useful (e.g. new data warehouse software solution). However, they do not actually know what solutions are available on the market and how they work in detail. *"We approach these issues by identifying potential fields of action and pointing out performance gaps where we think that something should work better than it currently does... Then we go out and talk to external technology experts to learn more about what can be done to address the performance gap"* [R27-I2].

BMW, KNORR, TKMS, and ZF further reported that the interaction with external technology experts during ideation did not involve any significant commitment or collaboration. *"At the early stages interaction is very much without any commitment. It is about gathering input and strengthening our understanding of specific issues in order to evaluate potential solutions. We are not talking about concrete implementation plans. Often there is not even any reference to specific products or technologies. It is a very general level we are talking about here"* [R28-I2]. The task forces did not perceive knowledge protection as a particular challenge during this stage; they did not need to provide any specific information to the external experts with whom they interacted, as the following interview excerpt reflects: *"We hardly give any internal to third parties at this stage. Question: Is that because it is not necessary, or because you want to protect your knowledge? Answer: because it is not necessary"* [R27-I2].

OPN-1.2: More specific interaction with technology experts: TEC provided evidence for a different pattern for interaction with technology experts during ideation in the context of proprietary core process technology. In contrast to the other cases, TEC's interaction with external technology experts typically moves beyond general information gathering. Relevant knowledge and technologies for TEC's core operations are often not readily available on the

market. Therefore, TEC has to create such information through specific interaction with external experts. This involves the assignment of selected external technology experts (e.g. research institutes) to perform specific research tasks. *"At first we worked in a joint project to carry out a feasibility study. Once we had the result we communicated them internally" [R24-I2].* The interaction with external experts helps TEC understand the feasibility of a potential solution. This requires the provision of significantly more internal information than the general search for information on the market. Reflecting on these situations, an interviewee stated: *"We have to explain how we configure and set-up our machines" [R19-I2].* This approach allows TEC to front-load the specification of process ideas and absorption of relevant knowledge in order to operate largely independently of external partners as early as possible. Similarly ZF corroborated that *"when speaking of core process development, however, we de-couple from external partners as early as possible and try to work out solutions on our own. We want to have something that no one else has. That's why we are trying to largely do this without external support" [R27-I2].*

OPN-1.3: Frequent and in-depth interaction with consultants: The companies that reported working with management consultants during ideation (BMW and ZF) claimed that the interaction was usually frequent and in-depth. The task forces work closely together with the management consultants and provide significant amounts of information. The consultants are located at the company's site and guide the task force on the collection of data for process analysis and evaluation. The project management is led by the consultant but overall responsibility for the project remains with the company. The companies stated that it was generally possible to obtain methods for performance gap assessment without providing organizational knowledge to the external consultant. Nevertheless, they specifically argued that in order to adapt methods for application within the company, external consultants required substantial amounts of information, such as expectations, requirements, and the internal structures of the company. However, the task forces in BMW and ZF did not consider granting external consultants organizational insight an issue. They argued that methods transfer did not require sharing any information related to critical internal knowledge during ideation. Critical internal knowledge refers to proprietary contents such as product or production related specifications rather than structural knowledge about organizational structures or expectations in general. *"When we talk about all the projects in which we worked with management consultants in the past few years it was actually not necessary to talk about critical knowledge. Such projects do not require specific, critical knowledge, such as how our products are designed, or constructed, or how the manufacturing technology works" [R4-I2].* The task forces emphasized the benefits of working with consultants, given their substantial experience with similar problems in other companies. The companies reported the use of legal agreements for knowledge protection when working with consultants during ideation.

6.2   Lifecycle stage 1 – Ideation: Discussion

The results show that during ideation, companies face the challenge of identifying and evaluating potential process solutions when there is limited knowledge on new technologies, potentially necessary organizational change, and systemic impact. Corroborating earlier studies (Frishammar et al., 2011, 2013; Gerwin, 1988; Kurkkio et al., 2011), the results describe ideation as a stage of significant uncertainty. Within this context, the results indicate that companies work with external partners to leverage external knowledge and methodological support. The following discussion elucidates the emergent themes on open process innovation across the different framework categories at the ideation stage.

6.2.1   Differences in technological change and the involvement of external experts

Preferences for process candidates involving technological rather than organizational change were a common finding during ideation. This was reflected in the way the task forces approach mutual adaptation, as well as technological and organizational change. All companies typically preferred to focus on potential solutions that involved the development or modification of new technologies while maintaining the existing organizational structures, processes, and skills. As a result, technology experts were the main source of external information during ideation. While the existing literature primarily highlights the role of technology suppliers as sources for technological information (Gerwin, 1988; Rönnberg-Sjödin, 2013), the results in the present study show that the companies initially search more broadly for technological information than the existing literature suggests. Furthermore, the results reveal differences in search depth depending on the relevance of the technology for the company's core operations.

Differences between standard technology acquisition and proprietary technology development: The results show that the focus on industrial standard solutions moderated the general preference for technological change. The companies reporting on the development of enabling processes typically acquire solutions from outside vendors to leverage external developments and knowledge. In order to exploit the benefits of standardized solutions (e.g. continuous support, regular updates, modular interfaces) the adopting companies have to limit technological modifications. Because knowledge of standard solutions is available to the companies they can increase the focus on estimating organizational change that new technologies would require. The benefits and proven effects that external solutions offer (cf. Rönnberg-Sjödin, 2013) can provide the task force with leverage to address early opposition and pre-select potentially relevant solutions for decision making (Gerwin, 1988). In contrast to the adoption of industrial standard solutions, the development of proprietary technology, as described by TEC, affects the performance of core operations. Earlier studies show that

companies cope with uncertainty by using the existing organization and manufacturing strategy as a benchmark for technology development (Frishammar et al., 2013; Jensen & Westcott, 1992). The results of the present study show that this approach is particularly relevant for the development of new core process technology. On the one hand, the new technology development marks an opportunity for companies to exploit internal capabilities in core operations and create unique solutions that set them apart from competitors. On the other hand, the TEC case also illustrated that the availability of external information may be limited. Using a known system such as the existing organization as a benchmark for new technology development minimizes the uncertainty involved in such endeavors.

Differences in search breadth: The results of present study suggest that differences in the availability of external information on standard processes and core processes affect the breadth of external search processes. The results show that the companies obtain information for the description of enabling processes candidates from a broad spectrum of external knowledge sources. These include hardware and software suppliers, research institutes and universities, companies in other industries, and competitors in industrial consortia. From the companies' perspective, the broad external search during ideation is driven by the motivation to generate an overview of available solutions. Relevant knowledge about established standard solutions that cater large markets is likely distributed across a broad spectrum of knowledge sources (Laursen & Salter, 2006). In order to identify incremental differences between potential solutions, industrial best practices, and future trends, the companies explore the full range of external search channels (Reichstein & Salter, 2006). From a more theoretical point of view this shows that at the outset of the innovation lifecycle companies search much broader than the existing open process innovation literature suggests (Lager & Frishammar, 2010; Rönnberg-Sjödin & Eriksson, 2010; Rönnberg-Sjödin, 2013). However, this finding mainly relates to the development of enabling processes, where external solutions are readily available and relevant information is accessible. The experience of the TEC task force shows that external information is often not available for core process technology. As companies need to gather relevant knowledge for the pre-selection of potential process solutions, the lack of information can be a significant problem during this stage. The case of TEC reveals a search process to cope with this problem that differs from the search described by the other companies. Despite, a broad initial search to understand whether potential solutions are available, companies in a context like TEC may quickly narrow down their search and create relevant information through joint research efforts with few selected partners. The existing literature on open process innovation does not account for a possible lack of available information. Although, the results in the present study concur with earlier descriptions of narrow search approaches during the front-end of the process innovation lifecycle (Lager & Frishammar, 2012; Rönnberg-Sjödin et al., 2011;

Rönnberg-Sjödin, 2013), the case of TEC clarifies that such approaches are necessitated by the absence of readily available information. The engagement described by TEC resembles white-box technology transfer, rather than collaboration (Fliess & Becker, 2006; Ragatz et al., 2002). Yet, it implies a much narrower and deeper interaction than the search for standard solutions.

Differences in search depth: The results also reveal differences in the structure of interaction with external partners. Companies searching for standard solutions from a broad range of external sources obtain such information without in-depth interaction. The results suggest that it is unnecessary for companies to engage in in-depth interaction to gain an initial overview of potential solutions when relevant information is relatively easily accessible. The perception of many interviewees that interaction with external technology experts was not even an active contribution towards the ideation stage illustrates a lack of depth in the interaction with external experts. Nevertheless, the information that task forces obtain from external sources during ideations informs the initial description of process candidates. The evidence obtained from TEC further corroborates the effect of information availability on search depth. TEC reported that that less breadth and more depth was necessary during the early search for non-standard solutions. Because no relevant information on available solutions exists, TEC has to generate relevant information in order to create a set of potentially feasible ideas. This insight is in line with existing research on open innovation and shows that interaction for the development of new technology requires companies to draw more deeply on external knowledge sources (Reichstein & Salter, 2006). To minimize risk, TEC relies upon advancements of existing technologies and organization. In contrast to standard technology, there are fewer possible avenues for new technology development that largely builds on existing proprietary technologies. Companies can therefore advance their innovation efforts by searching for more specific information and investing in search depth rather than breadth (especially in conditions of high industry productivity growth) (Terjesen & Patel, 2014). The finding that early search may involve commissioning feasibility studies shows that tangible research results are critical for ideation under circumstances of limited information availability. Previous studies on the front-end of process innovation do not account for this contingency when they find the ideation processes to be mainly theoretical in nature (Kurkkio et al., 2011). On the one hand early engagement with external partners for technology conceptualization requires a company to share knowledge (e.g. provide relevant data and instructions to enable laboratory testing), expectations, requirements, and intentions on technology development that could be relevant to competing organizations, to enable the external partner to make a contribution. On the other hand, closer interaction with a limited number of external technology experts enables front-loading the conceptual design of new process technology. More specifically, for core process development the innovating company can access knowledge (theoretical and practical) of

potentially critical technology at an early stage, when it is unnecessary to provide the external partners with advanced details on a new process solution.

6.2.2 Organizational structures and management consultants

The results show that the structures, processes, and skills of the existing organization are critical determinants to the pre-selection of process solutions during ideation. Generally, the existing organization constitutes a reference framework for the evaluation of potential new processes (i.e. technical process design) (cf. Frishammar et al., 2013). While each idea may make sense in itself, the focus of ideation should be on ideas that integrate with the entire production system and enhance overall performance (Jensen & Westcott, 1992). While core technology development emphasizes a stronger proclivity for the development of technology to fit with the organizational status quo, the appropriation of benefits that standard technologies offer requires a stronger focus on organizational change (Brehm et al., 2001; Hislop, 2002). In both cases an in-depth understanding of the existing organization is imperative, either for using the organization as a benchmark for technology change or estimating potential organizational changes. This points to the importance of appraising existing processes (Al-Mashari & Zairi, 1999; Davenport, 1993; e.g. Worren et al., 2002). Nevertheless, the results repeatedly suggested that poor documentation, historical development, and heterogeneous process landscapes across the corporation impeded the appraisal of the existing organization. This is a critical challenge during ideation, because it makes it difficult to identify the potential scope of a project and develop a solid foundation for the evaluation of process solutions.

Management consultants provide support for process appraisal: The systematic appraisal of existing structures and processes is not a typical core competence of manufacturing companies. The ideation stage thus provides an opportunity for manufacturing companies to draw on external support to address this challenge. The present study specifically documents the role of management consultants as sources of knowledge of systematic methods for the appraisal and documentation of existing structures, processes, and skills. While Bessant and Rush (1995) point to the capacity of management consultants to help clients diagnose, define, and articulate their specific issues and needs, empirical studies on open process innovation (Lager & Frishammar, 2010, 2012; Rönnberg-Sjödin, 2013) have not considered such contributions during the innovation lifecycle. Yet, the interaction with consultants is critical as it enables the company to establish the reference framework in which they evaluate technology and organizational change and the systemic impact of new solutions. In contrast to Lager and Frishammar (2012), the results show that it is management consultants rather than equipment suppliers who help identify needs of the company.

Project scope affects involvement of management consultants during ideation: The reports on the involvement of management consultants were however limited to projects with a broad scope (BMW; ZF). The results suggest that in broad scope projects, the potentially relevant existing structures, processes, and interdependencies are not immediately accessible. Methodological knowledge and sufficient capacity are necessary for process appraisal to inform the assessment of technological and organizational change as well as systemic impact. In narrow scoped projects (KNORR; TKMS; TEC) consultants are not involved during the ideation process. High costs for management consultants on the one hand and sufficient internal overview of the potential impact of a new process on the other render the involvement of consultants redundant. The case of TEC illustrated this finding particularly well. TEC's innovations directly related to the company's core operations technology, which is distinct from other companies and narrowly confined to the work organization within the production facility. The task force has a unique overview of the existing processes and interdependencies. The input of management consultants in terms of process appraisal and project scoping was therefore explicitly considered unnecessary, and even considered a potential threat with regards to the appropriation of proprietary knowledge.

Close interaction with management consultants: The results suggest that when companies interact with management consultants during ideation, the interaction is likely to be relatively more in-depth than interaction with technology experts. The results of working with management consultants form the basis for further idea generation. Given their fundamental importance, such contributions need to be obtained quickly and reliably. This explains why companies expect competence, quick response, and availability from consultants (Bessant & Rush, 1995) and shows that they have a strong incentive to reveal internal knowledge to consultants during the ideation stage. There is a strong risk involved in not sharing knowledge as investment in working with consultants might be in vain if they do not understand the company's specific circumstances. The results indicated that knowledge sharing with consultants was not a particular challenge. The knowledge that consultants require mainly relates to organizational structure and interdependencies. Such knowledge is of structural or declarative nature, i.e. it refers to know-that rather than know-how and is not typically confidential (cf. Jonassen et al., 1993).

6.2.3 Relevant capabilities for interaction with external partners during ideation

Recognition and exploration: The results suggest that task forces can assume an important gatekeeping role by exploring their companies' external environment (Cohen & Levinthal, 1990). The task forces in the present study enact this role through informal interaction with external technology experts at various occasions (cf. Lewin et al., 2011). The purpose thereof is to

recognize the potential value of external knowledge and to identify potentially relevant process candidates rather than investigating specific solutions in-depth. Similarly, Todorova and Durisin (2007) argue that recognition is about "…seeing or understanding the potential of the new external knowledge…" (p.777). This substantiates the implication of the present thesis' results that recognition is an important distinct component of a company's AC. Prior literature, however, often presents the recognition of external knowledge as a component of a broader "exploratory learning dimension", in which the company recognizes and understands new knowledge at the same time (Lane et al., 2006; Lichtenthaler & Lichtenthaler, 2009). The findings here present empirical evidence that understanding remains tentative during ideation. The information obtained from external knowledge sources does not yet enable the organizational members to fully understand the new technology, its application, or its impact.[19]

Previous research suggests that a company's ability to recognize external knowledge depends on the previous related knowledge it possesses (Cohen & Levinthal, 1990; Lane & Lubatkin, 1998; Zahra & George, 2002). The results in the present study show how task forces tap into the company's existing knowledge. The task forces in the present study seek to understand internal needs for example through interaction with selected internal stakeholders or by applying systematic methods to appraise existing processes and articulate performance gaps. In addition, the task force requires knowledge about relevant external knowledge sources. The results suggest that task forces can achieve this through engagement with various external technology experts such as universities, attendance at trade fairs, or membership in industrial consortia. Against this backdrop, the results of the present study indicate that in addition to the experiences of its members, the gatekeeping task force builds up an initial knowledge repository through interaction with internal stakeholders and external experts. This enables the task force to recognize the potential value of external knowledge and come up with process candidates during ideation.

Assimilation: Furthermore, the results show how, once task forces obtain new information, they translate it to the company-specific context to pre-select potential process candidates. The results show for example that high compatibility is an important criterion for technology pre-selection. To estimate compatibility conceptual adaptation occurs during the front-end of the innovation lifecycle. This means that companies outline adaptation theoretically rather than

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[19] This may be different in case of working with management consultants. When companies obtain methods for process appraisal from external consultants, they need to understand and apply the method. In order to do so the internal task forces need to understand external knowledge quickly. In order to support the adequate application of the method during ideation, it is therefore an option for the task forces to let external consultants apply the method. To ensure that consultants adequately apply methods to the company's specific context, companies may require specific capabilities for conveying company related knowledge to enable the partner to provide adequate methods. This may be easier if better connections have been established with the external consultant (Lichtenthaler & Lichtenthaler, 2009).

actually performing it. Conceptual adaptation thus indicates an early form of knowledge assimilation (cf. Lane et al., 2006; Todorova & Durisin, 2007; Zahra & George, 2002). This in turn allows supports the exploration of external knowledge by tentatively estimating its compatibility with the existing organization. The results of the present study suggest that this may occur through routines such as sketching out potential solutions, interaction with key stakeholders, or debate among the task force.

Transformation: Knowledge transformation, i.e. shaping the internal knowledge base does also occur during ideation, although it remains limited in scope. Sketching out potential solutions, performing early conceptual mutual adaptation, and debating process candidates, are all practices that the purpose of translating external information to company context as well as devising early estimations of potentially necessary changes to the existing organization and its knowledge base. The interaction with external partners seeds new knowledge among the members of the task and thus triggers early transformation of the existing knowledgebase (cf. Lewin et al., 2011). However, the diffusion of new knowledge within the company is key to earlier conceptualizations of the transformation component of absorptive capacity (Lane et al., 2006; Todorova & Durisin, 2007; Zahra & George, 2002), the results in the present study show that, apart from very few internal experts, the new pieces of knowledge are not yet disseminated within the company. The results thus suggest that during ideation transformation of a company's knowledge base is very much contained and occurs at the individual level (i.e. among task force members) but not yet at the organizational level.

Enablement: Despite the general patterns outlined above, differences prevail with regard to the availability of external information. In the case of standard solutions information is likely readily available. The results show that in this case informal interaction with external experts suffices for the task force to obtain relevant information. The task forces do not need to provide any specific internal information but collect and process generally available information in order to evaluate its relevance for the company. If external information is not readily available, as reported in the case of TEC, it needs to be created. In this case it may be necessary to describe communicate relevant expectations and requirements to external partners, for example for early conceptualization by research institutes, as the case of TEC shows. In sum, the results suggest that the interaction practices that companies perform during ideation serve the purpose of obtain information but also to enable external actors to create relevant information if necessary. Table 16 summarizes the findings relating to capability deployment at the ideation stage to show how practiced routines link to absorptive capabilities via their underlying meta-routines.

Table 16: Capability deployment: Ideation

Observable routines ➜	Common purpose ➜	AC Capabilities
Informal interaction with external technology experts at various occasions (informal and broad if information is available or more specific if information is not readily available)	Recognize potential value of external knowledge	▪ Recognition
Informal interaction with external technology experts at various occasions (informal and broad if information is available or more specific if information is not readily available)	Identify process candidates	▪ Exploration
Sketching out conceptual solutions; debating potential solutions among task force members	Translate external information to company context for pre-selection	▪ Assimilation
Sketch out and debate conceptual solutions; debating potential solutions among task force members	Early estimation of potential changes to existing knowledge base for pre-selection	▪ Transformation (limited)
Informal interaction with external technology experts at various occasions; describe relevant expectations and requirements for early conceptualization by research institutes if necessary to obtain information	Obtain information or enable external actors to create relevant information when not readily available	▪ Enablement

6.2.4 Summary of emergent themes at ideation stage

This discussion above elucidated emergent themes of the involvement of external partners during the ideation stage. The findings show that various external technology experts as well as management consultants can support companies coping with the uncertainty that characterizes ideation (see Appendix 10: Relationships between different levels of abstraction). The main emergent themes are as follows:

- **Theme 1.1: Motivation for interaction and type of process affect openness of interaction with external technology experts during ideation:** There are different approaches to addressing technological change during the ideation stage. In the case of enabling processes, ideation is characterized by a broad search though which companies access readily available information from external sources without close interaction. Ideation for core process technology development, in contrast, is characterized by a

narrower, yet more in-depth search as a result of the need to generate relevant information on potential technological opportunities and front-load conceptual development.

- **Theme 1.2: Project scope affects the relevance of management consultants as external partners during ideation:** Management consultants support companies in the creation of a reference framework, in which the evaluation of process candidates can take place. The findings suggest that management consultants are mainly necessary in projects with a broad scope, as the overview of existing structures, processes, operator skills, and interdependencies in this context is particularly complex but constitutes the basis for new process development.

- **Theme 1.3: Knowledge absorption is nascent, tentative, and confined to the task force during ideation:** The results show how companies deploy absorptive capabilities during ideation. In particular task forces assume a gatekeeping role as they interact with internal and external experts to understand internal requirements, recognize potential valuable external knowledge, and translate it back to the company specific context. Absorption remains tentative and confined to a small gatekeeping function within the company. Task forces need the ability to convey internal expectations and requirements to external partners if external knowledge is not readily accessible.

6.3 Lifecycle stage 2 – Adoption: Results

6.3.1 Framework category 1: Process innovation components (PIC)

Table 17 provides an overview of the sub-categories and their content relating to the process innovation components during the adoption stage as well as references to the cases from which evidence was drawn. The following sections outline these contents in more detail.

Table 17: Category: Process innovation components (PIC) - Adoption

Sub-category	Content	Case reference
PIC-2.1: Mutual adaptation as an important decision criterion	Plans for mutual adaptation have to be outlined to inform decision making	ALL
	General preference for minor adaptation efforts to minimize risks	ALL
	Planning for organizational adaptation necessary for standardization and standard technology introduction	BMW; KNORR; TKMS; ZF

(continued on next page)

Table 17: Category: Process innovation components (PIC) - Adoption

Sub-category	Content	Case reference
PIC-2.2: Technological concept development to reduce uncertainty	Concept development is carried out to specify technological compatibility, complexity, and relative advantage	ALL
	Compatibility as most important decision making criterion	ALL
	Concept development is necessary to emphasize limited understanding, achieve transparency, and create right expectations among decision makers	ALL
	Comprehensive description of complexity involved in solutions necessary	BMW; ZF
	Mainly theoretical planning of new solutions	BMW; KNORR; TKMS; ZF
	Early prototype development and substantial testing to understand new technology and specify relative advantage as early as possible	TEC
PIC-2.3: Organizational change considerations during decision making	General willingness to consider and accept organizational change but preference for minor organizational changes	ALL
	Organizational change necessary to exploit benefits of standard solutions	BMW; KNORR; TKMS; ZF
	Focus on maintaining organizational status quo	TEC
	Cross-departmental coordination of potential organizational change necessary	BMW; ZF
PIC-2.4: Systemic impact considerations during decision making	Systemic impact assessment is important for decision making because it enables a more complete process description	ALL
	Systemic impact is difficult to assess in-depth during this stage but interaction with key operators is important	ALL

PIC-2.1: Mutual adaptation as an important decision criterion: All companies in this study suggested that decision making required an outline of the necessary adaptation between new technology and the existing organization for any given process candidate. A common thread to all task force reports was a preference for minor adaptations and technological change to circumvent the inherent risk of change. Especially TEC emphasized this position. *"I would say that in selecting the topic of best fit between the new and the existing plays an important role. The main issue is how significant the difference to the existing organizational status quo is. It is a fact that changing the existing organization requires significant efforts. When I think about all our projects, 80-90% of them focus on changing or developing new technology. Organizational change hardly ever plays a role in the projects we work on" [R21-I1].* At the same time, the task forces in BMW, KNORR, TKMS, and ZF reported that introducing externally acquired standard technologies for enabling processes meant that organizational adaptation would clearly have to

be considered. *"When we make adoption decision, we have to take into account how well the technology fits with the processes and the organization that we have and what we may need to change" [R8-I1].*

PIV-2.2: Technological concept development to reduce uncertainty: All companies in this study typically carry out concept development to understand potential technologies in more detail. BMW, KNORR, TKMS, and ZF mainly develop conceptual solutions based on externally available information. Due to the lack of readily available external information, TEC develops early prototypes and carries out substantial testing for potential core process technologies. *"We try to gain as much in-depth insight as possible, to get comfortable with a potential solution. Of course we also have to carry out tests and provide evidence to show that the solution is feasible" [R19-I1].* Another TEC interviewee added that *"it requires a lot of time and very intense efforts [to develop technology concepts]. We have to consider what we have to do, when, and where early on. After all, these are our core processes. This is a delicate issue and a huge cost factor" [R23-I1].* All task forces considered concept development necessary to describe key parameters such as technological compatibility, complexity, and the relative advantage of new technologies with regard to various important dimensions such as efficiency, output quality, and safety. Technological compatibility was the most important criterion for decision making in order to antedate potential disruptions at later stages of the innovation lifecycle. *"At this stage we still have the option to choose the more suitable technology, which may cost more, but involves less risk because we can avoid major changes to technology or organization" [R8-I1].* All companies suggested that despite concept development, significant uncertainty always remained due to the limited technological knowledge at this stage. *"Ultimately, we cannot account for every contingency anyway" [R7-I1].* All task forces were therefore keen to create the right expectations among decision makers. *"I believe it is extremely important to explain to the internal stakeholder relatively early on that we are dealing with a complex process, with a complex technology, and that if we want to introduce, it requires efforts and investment into managing change. Initially, the process may be less efficient than the previous process, and it may take some time until the potential of the new process can be fully exploited. This can in some cases take one, two or even three years until I really achieve what I wanted to achieve. The stakeholders have to understand that" [R2-I1].* In this respect, ZF explained that it was important to apply comprehensive, transparent methods for the description and evaluation of new processes, in order to enable and document the decision making process. As one interviewee clearly stated: *"The decision is always made on basis of the transparent evaluation of as many criteria as possible" [R29-I2].*

PIC-2.3: Organizational change considerations during decision making: All companies explicitly stated that potential organizational changes had to be taken into account when developing coherent process descriptions. *"We always adopt a holistic approach, we assess what*

we have to change in terms of existing procedures, new technologies, existing organization, and how we to proceed regarding the process rollout" [R2-I1]. According to the reports, the task forces consider it more difficult to specify clearly the scope and details of organizational changes than technological change during this stage. TEC, in contrast, reported that the main aim was to make new technology fit with the existing organization. In fact, it was a common result across all cases that for core process development, the task forces expected a strong decision making preference for solutions involving technological change while maintaining the organizational status quo. The task forces in BMW, KNORR, and ZF suggested that a better understanding of the functions and departments affected by a process candidate emerged during concept development. Dealing with projects with a very broad scope, the task forces in BMW and ZF especially emphasized the challenge of discussing and coordinating change between relevant representatives of different departments and stakeholder groups within the corporation. *"Each department has its own responsibilities... When change is pending, we have to get together and agree upon the best solution. It is not the case that one group can simply dictate a solution and tell all others what to do. It is a discursive solution finding process and requires a lot of coordination" [R28-I1].* The reports further suggested that changing existing functions, responsibilities, and relationships (hierarchical structures) created stronger opposition from internal stakeholders than changing existing work processes while largely maintaining existing structures and responsibilities.

PIC-2.4: Systemic impact considerations during decision making: All companies in the present study reported that systemic impact should be taken into consideration during concept development and decision making. BMW, for example, clearly stated that systemic impact assessment was important to determine more comprehensively the ultimate benefit of an innovation. TEC in particular emphasized the importance of assessing the expected impact of process candidates on production output quality and quantity, and of identifying potential interferences with the existing production system. All companies agreed that despite careful concept development, process descriptions often remained too vague at this stage to carry out a sensible systemic impact assessment and identify all the relevant benefits, synergies, pitfalls and risks with certainty. *"Assessing the broader impact a solution in such a large company is generally difficult and expensive. It may however be unavoidable" [R28-I1].* Similar as at the ideation stage, the interaction with key operating personnel is a key mechanism to estimate the systemic impact of process candidates. *"These effects can often be identified more accurately by the operators working in production because they deal with the operations on a daily basis whereas we are involved with the planning or management" [R5-I5].*

6.3.2 Framework category 2: Motivation for interaction with external partners (MOT)

Table 18 provides an overview of the sub-categories and their content relating to the motivation for interaction during the adoption stage, as well as references to the cases from which evidence was drawn. The following sections outline these contents in more detail.

Table 18: Category: Motivation (MOT) - Adoption

Sub-category	Content	Case reference
MOT-2.1: Access to technological information	The interaction with technology suppliers mainly serves the purpose of obtaining relevant technological information	ALL
	Access readily available information on existing solutions from technology supplier	BMW; KNORR; TKMS; ZF
	Benefit from external expertise for generating relevant information on new technologies	TEC; (ZF)*
MOT-2.2: Methodological support as motivation for interaction with management consultants	Management consultants can provide methods and expertise for creation and evaluation of process candidates	BMW; ZF
	Management consultants may lack experience for non-standard solutions	TEC
	Consultants may not sufficiently understand the company's business model	TKMS
	Consultants often lack acceptance among operators	ALL

ZF provided additional, corroborating evidence for this content

MOT-2.1: Access to technological information as motivation for interaction with technology suppliers: All task forces reported interacting with different technology suppliers to obtain relevant information and details on potential new technologies. BMW, KNORR and TKMS, for example, explained that technology suppliers provided relevant, experience-based expertise on new technologies. This includes information on estimated time and cost for technology development, installation, and ramp-up, but also estimations of qualitative and quantitative improvements in operations. *"Of course it is often our intention for them to give us information at this stage. It may be the case that a supplier offers an interesting technology and has already implemented it in three other companies. Then, of course, it is our expectation that this supplier can tell us exactly what to watch out for, what potential pitfalls there are, how long the implementation may take, and so on" [R2-I2].* Nevertheless, the reports also suggest differences in the way suppliers deliver information during this stage, depending on the type of process technology. The companies reporting on external technology acquisition for the development of enabling processes (BMW; KNORR; TKMS; ZF) seek access to readily available information on existing standard solutions. The feedback from the technology providers' informs the task force about technological possibilities and thus shapes the process description. The task forces in

TKMS, for example, further recalled that *"…several times the supplier clearly opposed certain ideas for technology adjustments and would tell us that it makes no sense to make a specific adjustment because it does not fit the system's philosophy. I actually perceived it as very positive that not everything was implemented blindly, but that a discussion took place" [R13-I2].* When technology suppliers explain that certain expectations cannot be met through technological change, the task forces understand that the need for organizational change is implied. TEC, in contrast, reported that the main motivation for interaction with suppliers of technological components during this stage was to benefit from external expertise in creating relevant information, because relevant technological solutions were typically not readily available from external sources. *"We then had to create the relevant information we needed for decision making" [R24-I2].*

MOT-2.2: Methodological support as motivation for the interaction with management consultants during concept development and decision making: BMW and ZF provided evidence of interaction with external management consultants during the adoption stage. According to the reports by BMW and ZF, consultants facilitate decision making by providing methodological tools for the systematic and transparent development and evaluation of process candidates. *"When it comes to really using an external to define the actual solution, then I would definitely set the focus of collaboration during in the early stages. At the early stages we are actually concerned about getting the basic approaches right. That is when we need input from the external partner" [R2-I2].* In contrast to the ideation stage, the methods at this stage mainly serve evaluation purposes rather than benchmarking and process appraisal. ZF pointed out that management consultants provided methods to identify relevant decision making categories and use them during decision making. *"If we look at the consultants we are currently working with, they provide methodologies and support us with systematic idea generation and help develop and apply the methods for idea evaluation and decision making" [R32-I2].* The task force in BMW explained why consultants were so important. *"They can support us with the application of methodologies for evaluating possible alternatives, performing analysis, reaching decisions, and so on. In my view, such consulting partners are important because we often have the problem that we have internal experts, process specialists, but they are not necessarily the ones with the big picture in such large projects. They do not have the competencies to make systematic comparisons to enable decision making. That is why it can be very helpful to have an external partner who can provide exactly such methodological support" [R2-I2].* In this context it is particularly useful for companies if management consultants have gained expertise from similar projects in other client companies. This insight was also confirmed by TEC stating that , which reported on the development of unique, proprietary technologies, where consultants are less likely to have relevant experience. One interviewee stated: *"we design the processes and know the operators*

working in production and therefore often know much better what they need than any external consultant" [R18-I2]. Likewise, TKMS was particularly concerned that consultants did not understand the company and its business model well enough to ensure that their methods fit their specific context. While only BMW and ZF specifically reported on the involvement of external management consultants, all companies commented on the problems of working with consultants. The companies clearly considered the *"…limited acceptance that operators display for external partners" [R25-I2]* as a major impediment to the support of consultants in the development and evaluation of solutions.

6.3.3   Framework category 3: Openness during adoption (OPN)

Table 19 displays the content relating to the emergent sub-categories of openness during the adoption stage, as well as references to the cases from which evidence was drawn. The following sections outline these contents in more detail.

Table 19: Category: Openness (OPN) - Adoption

Sub-category	Content	Case reference
OPN-2.1: Interaction with technology suppliers during concept development	Decision making is an exclusively internal responsibility	ALL
	Interaction with technology suppliers is limited to the presentation of technological solutions; no collaborative research efforts; companies do not provide substantial amounts of specific information to technology suppliers	BMW; KNORR; TKMS; ZF
	Substantial information exchange on new technology and active collaboration for conjoint prototyping if suitable solutions not available on the market	TEC
	Conveying internal expectations and requirements to external technology suppliers is necessary to enable external contributions	ALL
	Technology supplier does not require critical data to present solutions	BMW; KNORR; TKMS; ZF
	Provision of specific technological knowledge necessary makes knowledge protection an important managerial issue	TEC
OPN-2.2: Structure of interaction with management consultants during decision making	Close interaction is necessary but the project lead typically stays with the company	BMW; ZF
	Structural knowledge can be shared with the external consultant	BMW; ZF

OPN-2.1: Interaction with technology suppliers during concept development: The task forces in BMW, KNORR, TKMS, and ZF reported that the depth of interaction with external technology suppliers during adoption was typically weak. The interaction with technology

suppliers is mainly limited to the suppliers' presentation of potential solutions and does not involve collaborative research effort, or the provision of substantial amounts of specific information. *"We had identified and shortlisted several suppliers that we invited, so that they could presented their software" [R13-I2].* The companies provide the technology suppliers with a catalogue of their expectations and requirements in order to enable the presentation of external solutions. These catalogues ensure that suppliers provide relevant information. In addition, as ZF pointed out, that they created a standardized basis for the evaluation of solutions. BMW, KNORR, TKMS, and ZF did not perceive knowledge protection as a particular challenge at this stage. The companies do not have to share proprietary information, in order to enable the suppliers. Instead, they share information about the organizational and technological infrastructure or meta-data such as the format or amount of data a technology has to process. The task forces across the companies believed that such information was not critical. *An interviewee in ZF stated: "It is not a big secret behind it what our IT landscape looks like or what software we use" [R29-I2].* Similarly it was clarified in KNORR that*:"the problems are pretty much the same in every company. The data management processes, in terms of how the major systems work, are almost identical" [R7-I1].* ZF and BMW suggested that in a few exceptional cases, when external partners required critical product or production related data to demonstrate a solution, "dummy data" were provided. In this context, legal agreements are the basic mechanism for knowledge protection for any formal interaction at the adoption stage. *"The four system suppliers that showcased their solutions, signed confidentiality agreements. Use cases were published as MS Excel files, or as PDFs. Sample data were revised by us and "dummified" so that we would not publish original, critical data. The use cases relate to the process not to the product. The sample data that are product specific, were anonymized" [R32-I2].* All companies acknowledged that early collaborative concept development efforts with external partners could be necessary if suitable solutions were not available on the market. TEC in particular emphasized this contingency. *"Our projects often require initial basic research. When we looked at laser-cutting, as an alternative approach to stamping, for example, and we could not find any relevant information. We had to do different experiments, make various developments, and tests. If we find that such tests do not suffice, we also collaborate with universities or research institutions. Once we have enough evidence to determine a potential benefit of a new solution we proceed to plan the next development steps" [R21-I1].* Both partners exchange substantial amounts of information on the new technology and actively collaborate for joint prototype development. As in the other cases, TEC reported that its expectations and requirements of a new technology but also includes the provision of specific technological information. *"Then, of course, the supplier told us that we needed to provide a description of process steps and also some product samples. We only provided all that so that the supplier could develop a concept how to make these components we needed and to give us an estimate of what this would cost us" [R19-I2].* The results in TEC show that in

addition to legal agreements the company mainly relies on the careful choice of external partners to protect itself against knowledge leakage.

OPN-2.2: Structure of interaction with management consultants during decision making: BMW and ZF reported that interaction with consultants was necessary to obtain tools and methods for systematic and transparent process candidate evaluation and decision making. BMW and particularly ZF explained that the role of consultants at this stage was restricted and predominantly centered on the provision of these tools. *"If we are certain as to the issue that we want to address, we have to look for a suitable consultant who can really solve this particular issue for us. Once we have found a consultant we discuss different possible approaches to structuring the problem and identify which methods and tools are the best in our case" [R28-I2].* The company considered it important that once these tools are in place *"...the management consultant operates in the background, to adjust the method if necessary, to review the effectiveness of the methodological tools" [R32-I2].* Similar to the interaction with technology suppliers the companies did not view knowledge protection as a particular challenge at this stage, as consultants do not usually require critical information. *"It can be quite helpful if the consultants attend out meetings in order for them to understand our organization and the problems we face but also for them to assess the way we apply their methods and tools" [R28-I2].*

6.4   Lifecycle stage 2 – Adoption: Discussion

The companies in the present study reported on the development and evaluation of conceptual solutions to inform decision making. The results showed that decision making required the conceptualization of new processes in order to determine their value to the company and to prevent unexpected disruptions at later stages. The adoption stage differs from ideation because it requires a more detailed conceptualization of process candidates and ends with an investment decision rather than a set of pre-selected ideas. As with ideation, however, uncertainty is characteristic of the adoption stage because potential solutions are not yet acquired or developed in detail (Frishammar et al., 2011; Gerwin, 1988). The results point to a lack of information during this stage. The technology is not yet fully developed or transferred into the organization. Typically, there are not sufficient resources available to test every potential solution in detail. Despite a general openness towards organizational change by the decision makers, the limited technological information makes it difficult for the companies to understand the immediate and systemic impact on the existing organization. The interaction with technology suppliers and management consultants therefore is a mechanism the task forces employ to address the challenge of decision making under conditions of uncertainty. The demonstration of new technologies and the provision of methodological support for concept

evaluation are mechanisms by which the companies in this study tapped into external advances in technology development and expertise in methods development. This suggests that rather than investing in the development of each solution in detail, the task forces rely on the technological developments and knowledge of external experts to address uncertainty and develop conceptual solutions. The following discussion documents the emergent themes on open process innovation across the different framework categories at the adoption stage.

Gaining top-management commitment: It is well-established in the literature that top management commitment is a critical enabler of successful process innovation (Frishammar et al., 2012; Meyers et al., 1999). In this context, Gerwin (1988) suggests that task forces bias their recommendations to decision makers towards the solutions they favor. According to Gerwin, decision makers will anticipate uncertainties and bias remaining in the task force's recommendations and will thus be inclined to evaluate the task force's credibility, mainly with regards to its past performance and reliability. The present study does not provide sufficient evidence to support or refute a bias in the task forces' recommendations to decision makers.[20] Instead, it reveals that external technological information and established methods for concept evaluation provide credibility to the reputation of the internal task force's reputation among the decision makers. The evidence in the present study suggests that task forces are keen to sustain long-term support for an innovation project by creating confidence and realistic expectations among the decision makers. In particular, the task forces try to be explicit about the assumptions and risks underlying their project proposals in order to ensure that decision makers were aware of their decisions' implications. In this respect, externally generated information on new technology and transparent decision making methods helps the task force to increase the perceived objectivity and transparency of their proposals to decision makers (cf. Menon & Pfeffer, 2003). Despite the involvement of external partners in concept development and decision making, all companies in this study stressed the internal nature of decision making.

6.4.1 Technological change and the interaction with external technology suppliers

Technology suppliers were the most prominent external actors at the adoption stage across all companies in this study. The primary motivation for the interaction with technology suppliers was access to technological expertise during concept development. In order to facilitate investment decisions, the task forces have to present information on the key parameters of the potential new technologies, such as compatibility, complexity, and relative advantage. The early assessment of potential process innovation projects is important as it delivers the input for later stages of the innovation lifecycle and thus determines technical, impact, and value creation

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[20] An element of bias in the decision making process remains given that ideas have been pre-selected by the task force during the adoption stage.

(Kurkkio et al., 2011; Lager, 2011; Voss, 1988). In this respect, technology providers are critical knowledge sources (Athaide et al., 1996; Flowers, 2007). This also emphasizes the importance of the adoption stage as an opportunity to reduce uncertainty prior to committing to a specific solution and external partner. The present study particularly emphasizes the importance of external contributions to technology assessment and concept development and also the different approaches to interaction with technology experts during adoption. The results show that companies perceive conveying internal expectations and requirements to potential technology suppliers as a necessary pre-condition for receiving relevant external information during concept development and decision making. This pre-supposes that companies have identified expectations and requirements prior to decision making and before committing to a specific solution and supplier. Earlier research, however, finds that companies only identify their expectations and requirements of new process technology once they have committed to a specific supplier (Rönnberg-Sjödin, 2013). Comparing these findings offers a new perspective on the development of expectations and requirements. While the companies in the present study begin the adoption stage with an existing set of expectations and requirements, the evidence also shows that the companies adjust their expectations based on new information. This was specifically reflected in the insight that despite the technological nature of external information the task forces in various companies suggested that technological information also enabled them to estimate potential organizational change and systemic impact, and as a result change their expectations of a new process. In addition, the adoption stage may enable the companies to adjust their expectations of the supplier's capabilities and culture, which will have an effect on the success of the interaction between the company and the supplier during the later stages of the innovation lifecycle (Petersen et al., 2005). In this respect the findings suggest that the adoption stage provides an opportunity to refine initial expectations and requirements and make the success of development work more likely. Nevertheless, all the companies emphasized that they kept decision making itself an exclusively internal process to remain without bias.

Different approaches to gaining technological information: The companies in this study interact with technology suppliers rather than a broad range of external technology experts at the adoption stage. This enables the task forces to focus their resources on more specific and in-depth search than during ideation, because they have to invest less in search breadth (cf. Terjesen & Patel, 2014). As outlined above, the companies' primary motivation for interaction with technology suppliers is to gain access to external knowledge in order to reduce the level of uncertainty in concept development and decision making. These insights concur with earlier studies on open process innovation from a lifecycle perspective (cf. Lager & Frishammar, 2012; Rönnberg-Sjödin et al., 2011; Rönnberg-Sjödin & Eriksson, 2010; Rönnberg-Sjödin, 2013). In particular, product demonstration and trial are important contributions to process innovation

by technology suppliers (Athaide et al., 1996). The present findings substantiate the critical nature of such contributions in context of concept development and decision making. The present study, for example, finds that external partners present technologies, provide information to identify technological compatibility against various benchmarks, and facilitate the estimate of potential impact and organizational change.

The present study adds to earlier literature by revealing different approaches to gathering technological knowledge depending on the relevance of new process technology for a company's core operations. The companies that reported on external standard technologies mainly interact with suppliers during technology presentations. In the case of core process innovation, as particularly emphasized by TEC, the evidence shows that interaction during adoption is relatively more in-depth as it involves the joint creation of preliminary solutions and technology prototypes. While both approaches serve the same purpose, the structure of interaction to access external information differs. The results on the companies' perception of the importance of knowledge sharing and protection also reflect this insight. The results show that the task forces require more specific information during adoption than during the ideation. The relevant previous knowledge that the companies have obtained during ideation, enables them to gather more specific information. At the same time they have to provide more specific information in order receive relevant and specific information. This suggests that the motivation to obtain more specific information leads to a general increase in the depth of interaction. While increasing depth was a common thread in the reports on the development of core and enabling processes, the managerial challenge of knowledge sharing and protection differed between both.

External partners are likely to possess significant experience with enabling processes that are similar across various companies. The companies that reported on such enabling processes directed their knowledge protection efforts towards the data to be fed into new technology than the structural knowledge relating to the technology and the process itself. Legal methods suffice and knowledge protection does not present task forces with a particular managerial challenge. In the few cases where suppliers required data to present solutions the data had to be "dummified".

For the conceptual development of core process technology, the results indicate that it may be unavoidable for companies to provide partners with specific information that directly relates to core operations. This seems necessary to obtain support from external partners. The joint development of prototypes requires at least some exchange regarding details of how the new technology works. This can advance the companies' progress of new technology development. Yet, interaction relating to core processes is a delicate issue, because it may reveal core knowledge to an external partner. The results suggest that legal methods do not necessarily

suffice to protect critical knowledge. In this context the routines that TEC outlined to protect its knowledge during interaction with external actors reflect the concern for knowledge protection during the adoption stage (see section 5.3).

The findings on increasing depth and concern for knowledge protection during adoption add to the extant literature on open process innovation, which identifies the concern for knowledge protection as occurring mainly at the development stages (Lager & Frishammar, 2010; Rönnberg-Sjödin, 2013). The present study provides evidence that interaction with external partners is critical to process innovation prior to technology development. Furthermore, the present study suggests that companies deploy different practices of knowledge protection during concept development of enabling and core processes, as the relevance of restricting external insight differs between both.

6.4.2   Methodological support for decision making

The results suggest that management consultants are important during adoption because they contribute to the evaluation of process candidates. Nevertheless, it appears that management consultants are less prominent sources of external knowledge during adoption than technology suppliers. It is an important insight that they are only involved by those companies in the study that typically have to make decisions that potentially affect various stakeholders and department when developing new processes, i.e. enabling processes with a broad scope (BMW; ZF). The evidence obtained from TEC, provides theoretical replication of this insight. TEC reported on narrow scope projects for core process technology development and typically with very limited information availability. In contrast to the other companies TEC explicitly does not involve management consultants during adoption.

From an open innovation perspective this means that external consultants advance internal innovation processes, although their knowledge contributions do not directly relate to new process descriptions. Instead, they provide methodological support which facilitates decision making. It is well established that transparent decision making methods are critical to supplier selection (de Boer et al., 2001). Likewise, the results show that the selection of process candidates requires transparency and objectivity (cf. Gerwin, 1988). The findings in this study show that the companies obtain such methods from external consultants. This is an important external contribution because it enables companies to systematically structure their decision making and supports the comparison of potential solutions and the selection of the best most appropriate one (Bessant & Rush, 1995). Moreover, these evaluation methods also provide evidence of the companies' ambition to restrain the bias of external political involvement. Consultants can therefore strengthen the foundation of any further development and

implementation work during the subsequent stages of the innovation lifecycle. While the results suggest a close interaction with management consultants, BMW and ZF clearly emphasized that decision making remained an internal responsibility. The results suggest that close interaction is possible because management consultants typically do not require access to information that relates to confidential knowledge. Therefore, knowledge protection is not a particular managerial challenge at this stage.

6.4.3 Relevant capabilities for interaction with external partners during adoption

Further exploration: The results suggest that further exploratory learning occurs during adoption, as companies develop conceptual process solutions in more detail (cf. Lane et al., 2006). In this context, the results in this study reveal practices such as working with external partners to develop early prototypes, inviting suppliers to present solutions, collecting feedback from internal experts, estimating organizational change and systemic impact, and developing concepts during adoption. The common purpose of these practices and routines is to probe the potential benefits of process candidates in order to facilitate decision making. Relative to the ideation stage, adoption requires a more in-depth exploration of external knowledge. This is possible due to the previously gathered information, which enables the task forces to carry out more specific search.

Further knowledge assimilation and transformation: The task forces reported obtaining information on new technologies from a range of technology suppliers during adoption to understand new knowledge sufficiently well to elicit its implications for the company-specific context. This clearly points to the deployment of assimilative capabilities during adoption, as Zahra and George (2002) define assimilation as a company's "routines and processes that allow it to analyze, process, interpret, and understand the information obtained from external sources" (p.189). The results in this study show that task forces may perform assimilation through practices and routines such as for example interaction with selected external technology experts, technology presentations or prototype development, and collecting feedback from internal experts.

The results show that during adoption external knowledge assimilation is guided by the company's expectations and requirements of the new process. The task forces, for example, provide use case scenarios to suppliers to provide a conceptual frame for the presentation of potential solutions, i.e. new knowledge. This enables the company to assimilate new knowledge within existing cognitive structures (Todorova & Durisin, 2007). On the other hand, the new information enables the task force to refine its initial expectations and requirements based on increasing understanding of new information. As outlined further above, external technology

partners highlight the limited adaptability of standard technology, which can change the task force's initial expectations of technological change. This purpose underlies the capability to transform existing knowledge within the organization by which companies "…recognize two apparently incongruous sets of information and then combine them to arrive at a new schema" (Zahra & George, 2002, p. 191). This suggests that assimilation of new information and transformation of existing knowledge occur at the same time, through similar routines, and interdependently.

In contrast to ideation, the adoption stage shows that absorptive capacity is no longer just confined to the task forces and their ability to understand external information. New information is increasingly disseminated to other stakeholders within the organization, although not yet very broadly. Other members of the organization need to be able to absorb the knowledge (Cohen & Levinthal, 1990), and this requires the organizational skills to communicate and transfer knowledge back into the company (Lewin et al., 2011; Zahra & George, 2002). The results in the present study, for example, show routines and practices such as communicating process solutions to decision makers and collecting feedback from internal experts. Nevertheless, the results re-emphasize the role of the task force as a gatekeeper who "translates" information and communicates it to internal stakeholders in order to enables broader transformation (Cohen & Levinthal, 1990).

Enabling external contributions during the adoption stage: The results suggest that the more specific search during adoption requires companies to convey relatively more internal knowledge to outsiders than during ideation. This presupposes that task forces have an ability to understand internal needs and to convey them to the external experts. Conveying internal knowledge to external partners also presupposes skills and routines to cope with limited time, the external experts' limited knowledge of the company, and the managerial challenge of shielding critical internal knowledge from outsiders. The routines by which the companies in this study enact this capability to enable external partners include, for example, the provision of use cases scenarios, as in the case of ZF. Furthermore, core knowledge may be protected by such practices as only working closely with those external partners that pass a specific risk minimizing criteria, as outlined by TEC. Table 20 summarizes the findings relating to capability deployment at the adoption stage to show how practiced routines link to absorptive capabilities via their underlying meta-routines.

Table 20: Capability deployment: Adoption

Observable routines ➜	Common purpose ➜	AC Capabilities
Working with external partners to develop early prototypes; Inviting suppliers to present solutions; collecting feedback from internal experts; estimating organizational change and systemic impact; developing concepts	Probe potential benefits of process candidates	▪ Exploration
Interacting with selected external technology experts; Technology presentations or prototype development; collecting feedback from internal experts	Understand external information in more detail and sufficiently well to clearly describe solutions and establish project plans	▪ Assimilation
Collecting feedback from internal experts; estimate organizational change and systemic impact based on new information; developing concepts	Initial internal knowledge diffusion to refine expectations and requirements based on increasing understanding of new information	▪ Transformation (limited)
Providing use cases to external technology partner; provide information for joint prototype development	Convey information to external partners to enable provision of relevant information	▪ Enablement

6.4.4 Summary and emergent themes at adoption stage

The discussion above identified emergent themes on the involvement of external partners during the adoption stage. The results provide support for the proposition that interaction with external actors is a key antecedent to process development (cf. Frishammar et al., 2012, p. 6). While decision making is an internal responsibility, the present study suggests that external actors support the processes leading to the decision. In particular, the companies in the present study leverage external knowledge and methods for technological concept development and increasing transparency in decision making (see Appendix 10: Relationships between different levels of abstraction). The main emergent themes can be summarized as follows:

- **Theme 2.1: Motivation for interaction and type of process affect openness of interaction with external technology experts at the adoption stage:** Depending on the availability of relevant external solutions, technology suppliers present their solutions or help the task force to develop conceptual prototypes. Information is relatively more readily available for standard solutions than for proprietary core technologies. Interaction with external experts focuses more on suppliers and becomes more in-depth. Knowledge sharing and protection thus become more relevant than

during the ideation stage. Especially for concept development in core process technology knowledge protection requires particularly careful managerial attention.

- **Theme 2.2: Project scope affects the relevance of management consultants as external partners at the adoption stage:** Management consultants contribute to adoption by providing methods for the systematic and transparent evaluation of process candidates. Support from management consultants is mainly relevant in projects with broad scope.

- **Theme 2.3: Further knowledge absorption occurs with particular focus on adjusting expectations and requirements at the adoption stage:** Adoption comprises concept development and decision making. This involves further, albeit more in-depth, exploratory learning. The task force needs the ability to assimilate new knowledge sufficiently well to create detailed, yet preliminary process descriptions. At the same time, the task force needs the ability to transform its own existing knowledge base to make use of new information. Furthermore, a company requires the structures and abilities to diffuse new knowledge to key stakeholders. Finally, the task force requires the ability to enable external partners by conveying internal knowledge to external actors while accounting for different knowledge protection contingencies.

6.5 Lifecycle stage 3 – Preparation: Results

6.5.1 Framework category 1: Process innovation components (PIC)

Table 21 provides an overview of the sub-categories and their content relating to the process innovation components during the preparation stage, as well as references to the case from which relevant evidence was drawn. The following sections outline these contents in more detail.

Table 21: Category: Process innovation components (PIC) - Preparation

Sub-category	Content	Case reference
PIC-3.1: Managing the coordination of change during preparation	Technological and organizational change need to be coordinated with relevant firm internal stakeholders to obtain feedback and address expectations and requirements	ALL
	The operators become increasingly aware and opposed against change and in particular organizational change	BMW; KNORR; TKMS; ZF (TEC)*

(continued on next page)

Table 21: Category: Process innovation components (PIC) - Preparation

Sub-category	Content	Case reference
	Increased focus on interaction with key operating personnel to achieve feedback and create acceptance for change	ALL
PIC-3.2: Understanding and developing technology	The preparation stage is an important opportunity for the task force to learn about new technology and cope with increasing complexity	ALL
	Achieving technological compatibility as main objective of technological change during preparation	ALL
	Limited technological modification in order to exploit benefits of standard solutions	BMW; KNORR; TKMS; ZF
	Develop technology to fit with the existing organization	TEC
	Challenging to communicate unfinished solutions	BMW; TKMS; ZF; TEC
PIC-3.3: Planning and coordinating organizational change	The acquisition of standard solutions (and the standardization of processes) requires a stronger focus on organizational changes	BMW; KNORR; TKMS; ZF
	Changes need to be coordinated across all affected departments and functions	BMW; ZF
	To create acceptance for organizational change the task forces have to convince stakeholders of the new solution	BMW; KNORR; TKMS; ZF
	Changing existing work processes causes less resistance than structural change (e.g. roles, responsibilities, power, etc.)	ZF
PIC-3.4: Assessing systemic impact	It is important to assess potential systemic impact as the solution is developed but it remains difficult to anticipate impact precisely	ALL
	Different mechanisms can be applied to estimate systemic impact (e.g. simulation, prototyping, involvement of key operators)	TKMS; ZF; TEC

*TEC provided additional, corroborating evidence for this content

PIC-3.1: Managing the coordination of mutual adaptation during preparation: BMW, KNORR, TKMS, and ZF emphasized the importance of organizational adaptation to exploit standardized technological solutions. One KNORR interviewee explained the following: *"It is actually a gradual approach. When we implement a new technology, we first try to use everything out of the box and do not necessarily compare it with the existing solutions. Instead we focus on what is considered to be best practice with this new solution. Then we ask relevant stakeholders in the organization whether they can work with [the new solution] that way. Of course they always argue that the existing organization has specific requirements and then further technological change becomes necessary. However, in most cases technological adaptability is limited because*

otherwise the technology does not function properly anymore or it becomes too costly to maintain it" [R8-I1]. TEC, in contrast, specifically reported usually developing technology with a view to the existing production system (i.e. work processes, skills, and technological infrastructure). *"We do not ask that something will be changed in the current organization simply because we introduce a new element into the production processes. We do not want to disrupt the entire organization of the facility. We clearly focus on technological change" [R19-I1].* Furthermore TEC stated that: *"the technology is adapted to the existing organizational system. The technology is developed so that it fits with and can be applied within our existing structures" [R21-I1].* The task forces reported typically experiencing increasing opposition against change at the preparation stage. They suggested that during preparation stakeholders became increasingly aware of the pending changes but often felt uncertain as to how these might affect their own employment situation. This creates a particular challenge for the task forces that reported on the acquisition of standard solutions, which requires a stronger focus on organizational change. Against this backdrop, the task forces considered coordination and communication of technological and organizational change between relevant internal stakeholders (key operators, decision makers, and accountants) imperative for addressing and consolidating different expectations and requirements, obtaining feedback for further change, and fostering acceptance. *"It is always the case that people remain stuck in old structures and routines. They recognize the changes, but they do not accept them. They are presented something new, but it is often difficult for them to understand the purpose of the innovation. We really have to make the benefits comprehensible for them" [R13-I1].*

PIC-3.2: Understanding and developing technology: The task forces in BMW, KNORR, TKMS, and ZF suggested that the preparation stage provided an opportunity for them to understand new technology and its implications in-depth before further internal dissemination. *"When we engage with technological change and repeatedly discuss the new technology in-depth we increase the level of technological change specification and it suddenly also becomes much clearer what organizational adaptations are necessary" [R2-I1].* Consistent with the previous lifecycle stages, the task forces in all the companies studied agreed that approaching compatibility not only with the organizational structures, processes, and competencies, but also with the initial expectations and requirements was the main objective at this stage. Consequently, technology modification or developments were named as key activities during preparation. The task forces reporting on externally acquired solutions emphasized the importance of avoiding extensive technological modifications. *"Our ambition is to use standard software without modifications and simply configure it properly. Configuration instead of customization, if possible" [R28-I2].* TEC, however, reported achieving compatibility through technology development guided by frequent alignment checks with the existing organization and key operators. *"During preparation we*

regularly engage with organizational stakeholders to gradually improve our solution. Once we reach a new milestone we must somehow confirm to what extent the solution will be applicable. We gather feedback on our production tools prototypes to understand which issues should be addressed to make the solution applicable with the organization" [R24-I1]. The reports further suggest that for enabling and core process technology alike the communication of unfinished solutions is a particular challenge for task forces. *"At some locations, especially at large sites, where multiple segments are located, it was a bit difficult to teach them that they have a benefit from using a new, standardized solution" [R6-I1].* Likewise *and interviewee in TEC stated that "the operators here often have the attitude that they do not want change. They do not want it because they do not know it and they do not know how to work with it. That is why we have to provide training and carefully familiarize the operators with change" [R19-I1].*

PIC-3.3: Planning and coordination of organizational change: The task forces in BMW, KNORR, and ZF pointed out that organizational change required coordination across all affected departments or functions. In contrast to the earlier lifecycle stages *"the coordination can be better structured and organized more systematically, once we know the solution in detail. We can then directly address the departments that will be affected by a specific change" [R26-I1].* Nevertheless, the task forces clearly stated that coping with opposition to organizational change was a major challenge during preparation. *"Now we have move towards implementation. This is usually a difficult transition. Suddenly the people feel that they will be affected by change. They suddenly realize they will have to become active and that they need to change their working environment or they may have to work with new colleagues or get assigned to other tasks that they are not familiar with. Such issues lead to a sense of uncertainty which can significantly impede the realization of such projects" [R16-I2].* This was particularly relevant for organizational change as the result of limited technological adaptability in the case of externally acquired standard solutions. The following statement from KNORR reflects this issue: *"we have the goal that the software we use is actually highly standardized and we hardly have to make specific adjustments" [R7-I1].* The task forces therefore considered it necessary to clearly inform operators about the new process, its technology, organizational changes, and implications to address social uncertainty and foster acceptance, ownership, and create process champions among the operators. *"The acceptance of change is definitely much higher if we communicate change to the team early on during preparation and in some depth" [R19-I1].* Moreover, task forces considered it important having particularly well-articulated and convincingly presented arguments to prepare the deployment of organizational changes. *"We ended up emphasizing the added value of the standardized solution that would be eventually be realized, perhaps not for every individual, but in total, for the company or at least the specific division, if we implemented the process as to some extent required by the technology" [R1-I1].* The reports by ZF further elaborated on the

different reactions to different types of organizational change. According to ZF, changing existing processes while largely maintaining capabilities and responsibilities incurs relatively less opposition than changing organizational structures, hierarchies, responsibilities, and functional inter-dependencies.

PIC-3.4: Systemic impact assessment: The task forces across all companies in this study reported that it became easier to conduct systemic impact assessment during preparation than at the previous stages due to the increasingly specific process description. *"I know more about the interfaces that I have to take into consideration. I now also have to trigger activities in the broader process environment to ensure that the entire system will work as a whole in the end" [R2-I1].* TEC in particular highlighted the fact that systemic integration needed to be prepared prior to process implementation, in order not to disrupt existing operations. *"When we develop the technology in detail, we must continuously evaluate whether it still fits with the system into which it will be implemented. It is a challenging task to make a technology ready for use in real operations. We always discover new issues. Something will work fine in the laboratory but could never be implemented because it would not fit with our existing operations. Ultimately, however, we have to get the entire system up and running" [R23-I1].* The task forces in TKMS, ZF, and TEC described various mechanisms to assess systemic impact and integration. ZF, for example, explained: *"We have a large database tool, where we enter the entire results according to the methodology. We use that to run simulations. That helps us understand the impact of the change we aim to implement" [R32-I2].*

6.5.2 Framework category 2: Motivation for interaction with external partners (MOT)

Table 22 provides an overview of the sub-categories and their content relating to the motivation for interaction during the preparation stage, as well as references to the case from which relevant evidence was drawn. The following sections outline these contents in more detail.

Table 22: Category: Motivation (MOT) - Preparation

Sub-category	Content	Case reference
MOT-3.1: External support for technology development	Accessing external capabilities for technological change	ALL
	Access the capabilities of the supplier in modifying the technology; learn from the experience relating to the preparation, implementation, and use of the technology; understand the limitations of technological modification	BMW; KNORR; TKMS; ZF
	Access to externally developed technological components	TEC; (ZF)*

(continued on next page)

Table 22: Category: Motivation (MOT) - Preparation

Sub-category	Content	Case reference
MOT-3.2: Limited contributions to organizational change	Limited motivation to obtain external support for development and communication of organizational change	ALL
	Limited acceptance of management consultants impedes support for organizational change	BMW; TKMS; ZF
	Obtain indirect support for organizational change planning through technological knowledge	BMW; KNORR; TKMS; ZF; (TEC)**

ZF provided additional, corroborating evidence for this content
**TEC provided additional, corroborating evidence for this content

MOT-3.1: External support for technology development: All task forces reported interacting with external partners for technology development during preparation. However, the reports across the companies revealed different motivations for working with external partners, depending on the development of enabling processes (BMW; KNORR; TKMS; ZF) and core processes (TEC, ZF). BMW, KNORR, TKMS, and ZF reported the following motivations to work with technology suppliers during preparation: (1) accessing suppliers' capabilities for technology modification, (2) learning from prior experiences of technology preparation, implementation, and operation, and (3) learning about limited technological adaptability. The following excerpts from ZF and TKMS highlight the relevance of interacting with external partners during preparation. *"Then we increasingly proceed towards project implementation, where we relatively quickly strongly involve a software partner who helps us adapt the software, although we try to stick to what the provider has suggested as the industry-specific solution, when we adopt standard solutions" [R27-I2].* Similar experiences were described by TKMS. *"The supplier clearly discussed with us how we could do things differently, or that certain basic functionalities already delivered 80% of what is actually expected and that maintaining the basic functionality saves all the effort for ineffective adjustments. I remember quite a few projects where suppliers actually told us that certain changes would not make sense given our systems landscape" [R13-I2].* KNORR, TKMS, and ZF further specified that it was necessary to develop a technological understanding during preparation in order to configure and maintain the technology independently during installation and operation. TEC, in contrast, reported that technology was primarily developed internally. The external partner modifies and delivers technological components, while TEC develops the technological solution internally. *"Our partners deliver the components, but when we develop the new technology we aim to keep the development work largely in-house" [R25-I2].* Only in the case of insufficient internal capacity, does TEC assign external partners to work on technology development in close interaction with the internal task force.

MOT-3.2: Limited contributions to organizational change: All companies agreed that external partners could only contribute marginally towards organizational changes in response to technology changes during the preparation stage. All task forces considered planning, coordination, and communication of organizational change to be sensitive topics and carried them out internally. BMW, KNORR, and ZF suggested that the external partner's limited organizational insight regarding internal structures and processes impeded external contributions towards organizational change. An interviewee in BMW clearly expressed that *"when it comes to organizational changes, the external partners' competences are very limited" [R2-I2].* Furthermore, the task forces in BMW, TKMS, and ZF suggested that external consultants often lacked acceptance among internal operators. This made it difficult for them to prepare operators for organizational change. *"An external partner coming along proclaiming to have a specific job to do and ordering our people to do things … that never works. There always has to be a named, internal project champion who is responsible for coordinating the changes. The internal stakeholders have to be able to relate to a colleague who is in charge of this issue, with whom they have discussed why they need to contribute to the pending changes. That is essential. I cannot imagine that this would work without an internal champion" [R2-I2].* Nevertheless, KNORR, TKMS and ZF explained that they received information on typical areas of organizational change following from technology introduction when working with technology suppliers. As at the preceding stages the task forces also reported that technology suppliers reminded them of limited technological adaptability. This information enables the task forces to understand necessary organizational changes in more detail. One interviewee in ZF aptly stated: *"We always say that the limited adaptability of new standard software is limiting factor during preparation, a restriction, but that this is not necessarily a negative thing. It helps us to gain a an understanding of what adaptations would be possible regarding the software architecture, and equally which customizations would bend the software to an extent that it would not work properly, become too expensive to main, or lose compatibility with future upgrades" [R27-I2].*

6.5.3 Framework category 3: Openness during preparation (OPN)

Table 23 displays the content relating to the emergent sub-categories of openness during the preparation stage. The following sections outline these contents in more detail.

Table 23: Category: Openness (OPN) - Preparation

Sub-category	Content	Case reference
OPN-3.1: Structure of interaction for technology development	The interaction is in-depth because preparation is an opportunity to learn from the technology supplier	BMW; KNORR; TKMS; ZF

(continued on next page)

Table 23: Category: Openness (OPN) - Preparation

Sub-category	Content	Case reference
	Technology partner can assume responsibility for technological change but close interaction is necessary exchange information on technological change	BMW; KNORR; TKMS; ZF
	Preference for limited involvement of external partners for core process development to retain critical information in-house	TEC; (ZF)*
	The external partner is largely responsible for developing and delivering components but not full solutions	TEC; (ZF)*
	Technology development and assembly is largely carried out by the internal task force	TEC; (ZF)*
OPN-3.2: Knowledge sharing and protection for technological change contributions	Technological specifications, expectations and requirements need to be shared with the external partner to enable external contributions	ALL
	External partners do not require access to confidential information in order to support technological change	BMW; KNORR; TKMS; ZF
	Confidential information is necessary and needs to be protected during the development of core process technology	TEC; (ZF)*

ZF provided additional, corroborating evidence for this content

OPN-3.1: Structure of interaction with technology suppliers: The task forces in BMW, KNORR, TKMS, and ZF reported that throughout the entire innovation lifecycle interaction with technology suppliers was the most in-depth during preparation. For the transfer and modification of externally acquired solutions these companies narrow their search. *"During the preparation stage, we mainly interact with one selected software supplier. The development, programming is then carried out externally but we maintain close contact and also have the project lead" [R27-I2].* The task forces in BMW, TKMS, and ZF further specified that relevant expectations and requirements as well as specifications were passed on to the external partner. This may not only refer to trivial issues such as specific preferences for technological settings but also to existing structures and work processes that affect and are affected by the new process. The external partner performs the work or provides comments or further suggestions. Through mutual information exchange with the technology supplier, the companies develop relevant knowledge for technology utilization and maintenance, as the task forces in BMW, KNORR, TKMS, and ZF explained. *"Now we are almost in the phase where we are getting really close to installation and have developed some decent knowledge. This means that we can have in-depth discussions with our partners. This makes sense because we use this external assistance during preparation and to grow our expertise even further. At the beginning, a large proportion of*

new knowledge comes from external sources because we do not have sufficient internal experience. The longer the project takes, the more the internal experience grows, and the larger becomes the proportion of new knowledge that we create internally" [R8-I2]. For core process development, however, TEC and ZF reported restricting the involvement of external partners during preparation. *"Developing new core technology to fit with the existing organization carried out internally. We do not usually co-create such technologies with external partners"* [R24-I2]. The task force in TEC reported that new technology itself embodied critical knowledge. The company's primary aim in this context is to develop core technologies internally in order to restrict external insight and not to reveal information about critical technologies and operations. While the external partner develops and modifies key components, the technology (full process equipment) is developed and assembled internally. *"We order technological components or modules. However, at the end of the day, we try perform systems integration and the development of the entire technology in-house. We want to have a technology that is unique and we want the know-how to perform future changes to the technology. It is standard practice that a facility, especially when it was built in a very modular fashion, is regularly updated, modified, adapted or renewed. We need to be able to do this"* [R18-I2]. This way TEC leverages its internal knowledge advantage to build proprietary technology (this insight was also corroborated by the reports from ZF). *"During the preparation stage, we typically have less external contributions and use relatively little external input because this is a stage where we try the product, the technology in detail and work out how to implement it internally. We do that internally"* [R17-I2]. ZF corroborated this insight with regard to core process development. *"For the production technology it is the other way round. We try to keep as much work as possible internal"* [R27-I2]. When limited capacities make working with a specific external partner for technology development unavoidable, active engagement, information exchange, and coordination is necessary. This may have a negative effect on core knowledge protection. It was therefore particularly important for TEC to work with selected, exclusive partners that mainly operated in different industries.

OPN-3.2: Knowledge sharing and protection for technological change contributions: A common thread to the reports from all companies in the present study was the notion that task forces have to share knowledge and provide information when working with an external partner during preparation. All companies agreed that they had to reiterate their expectations and requirements of the technology to the external partners throughout the entire preparation stage. Nevertheless, between the development of enabling processes and core processes differences emerged with regard to knowledge sharing and protection. The companies reporting on the development of enabling processes (BMW, KNORR, TKMS, and ZF) considered knowledge protection as a minor challenge because they could work with suppliers for technology

modification without revealing confidential information (e.g. by sharing product and production related data). *"The external partner will then receive some detailed knowledge of a specific process sequence. There are ways to divide a complex process into several steps or sequences. The knowledge about these steps can be shared with external partners because they are the same at all big companies anyway" [R29-I2].* If necessary, "dummy data" can also be used. An interviewee in ZF explained the relevance of knowledge protection during the preparation of enabling processes in more detail. *"Of course, external partners support us with the technology development. But they do not have to access critical data to do that. Usually, we do not let our external partners access our real, productive systems. For development purposes we use a testing environment and such data that are not critical. We use that until we reach a level of maturity which allows us to actually implement a working solution. The implementation of the new solution into the real operating environment is carried out by us, internally, to restrict external access to real operating insights" [R27-I2].* In contrast to enabling processes, the results suggest that knowledge protection is more challenging for the development of core process technology. *"When we develop and introduce a new core technology it is difficult but absolutely necessary to control the flow of information from operators to the component suppliers. This is a big problem" [R23-I1].* In the case of TEC, the task force reported that knowledge protection was very important for new technology development. *"When it comes to sharing information on our core processes, personally, I always have some issues with that. Providing an external partner with all the information that would enable that partner to build the same technology that we have is something we try to avoid" [R19-I2].* TEC therefore reported applying several protection mechanisms in addition to legal agreements, including for example sourcing from various partners, working with partners from other industries, establishing long-term supplier relationships, and limiting the involvement of external partners. *"Secrecy is a big issue. If it is unavoidable to work with external partners, it is important that we have external partners we know and trust" [R23-I1].*

6.6 Lifecycle stage 3 – Preparation: Discussion

During preparation the task forces across all companies in this study adapt technology to the needs of the organization, work out organizational changes in response to new technology, and plan for the systemic integration of new processes. All these activities presuppose an in-depth understanding of the new technology. In this regard, the results showed that task forces engage in interaction with the suppliers of technologies or technological components. At the same time, the results document an explicitly limited involvement of external partners with organizational change. The results indicate that their limited acceptance by operators and restricted organizational insight constrains the extent to which external actors can contribute to

organizational change. The following discussion of these insights focuses on three key issues: the involvement of technology suppliers during preparation, the limited external contributions towards organizational change, and capability deployment for open process innovation during preparation.

6.6.1 The involvement of technology suppliers during preparation

The results suggest that even for standard technologies some degree of modification is necessary to meet a company's expectations and requirements. The companies that reported the development of enabling processes do not have the capabilities or the ambition to develop such solutions internally, as they do not relate to the companies' core capabilities and external solutions are readily available on the market. For well-established solutions, suppliers are likely to have strong technical capabilities and rich experiences of similar projects in other companies. The buying companies, in contrast, typically "know less than they buy" (Flowers, 2007). The technology supplier is therefore better equipped to perform technology modification than the buying company. In this respect the study concurs with previous literature that it is a key task for the technology supplier to customize or modify new technology (Athaide et al., 1996; Rönnberg-Sjödin et al., 2011; cf. Rönnberg-Sjödin, 2013). Furthermore, close collaboration enables the task force to learn about the new technology, which is important with regard to developing internal capabilities (cf. Flowers, 2007) and communication with internal stakeholders. Increasing interaction between the task force and key operators emerged as a key characteristic of the preparation stage. The present study thus corroborates earlier literature identifying operators as critical participants during preparation (Lager, 2011; Rönnberg-Sjödin, 2013). Due to their first-hand experience and familiarity with existing processes, the feedback of operators is central to detailed process development. Furthermore, interaction is necessary to familiarize operators with impending technological change. It is well established in the literature that pre-installation training not only makes operators more familiar with the technology and therefore more likely to accept it, but also improves their technical competences (Gerwin, 1988; Meyers et al., 1999). To clearly articulate the purpose, advantage, and impact of new technology, task forces need detailed technological knowledge. For external standard solutions task forces generate such knowledge through close interaction with the technology supplier. In contrast to earlier studies (Gerwin, 1988; Lager & Frishammar, 2010; e.g. Meyers et al., 1999) the results emphasize the role of the task forces as intermediaries between operators and suppliers. The task forces are in a unique position to coordinate change and transfer knowledge because they are familiar with the different internal stakeholder groups as well as with their expectations and requirements.

The results further show that the insights above only pertain to the development of enabling processes. As the TEC case illustrates, suppliers are unlikely to have a broad experience base of similar projects, when companies develop proprietary technology for core processes. The development of such new technology typically requires testing in the real operations environments (Lager, 2000). The results in the present study indicate that external actors are not supposed to gain insight into these operations. Instead, the internal task force in TEC aims to leverage its company-specific knowledge and to build on the knowledge generated through collaborative prototype development during the earlier lifecycle stages. Yet, the open innovation literature argues that due to increasing technological complexity and the wide-spread dispersion of knowledge even large companies endowed with many resources do not have the resources and capabilities to develop new technologies exclusively internally (Chesbrough, 2003). In this respect the results showed that TEC sources technological components externally but aims to develop new technology largely internally.[21] This approach enables TEC to secure the appropriation of its development efforts.

The managerial challenges involved in knowledge protection further reflect the differences in the structure of interaction with external technology suppliers in the development of enabling and core processes. The preparation stage provides a unique opportunity for the task force to engage in in-depth interaction with the technology supplier to learn about the new technology. As at earlier stages managing knowledge protection is not a significant issue. During preparation the aim is develop and test the technology in detail, but it is not yet integrated with the company's real operational system. While the new process becomes more specific than in previous stages, the new technology does not yet process any confidential data.[22] As at earlier stages "dummy data" may relatively easily replace accurate data, if necessary. For core technology, however, the technology itself embodies the critical knowledge that companies aim to protect. This makes the interaction with external partners relatively more problematic than for standard technology acquisition. Working with technology suppliers bears the risk that a company's existing knowledge leaks to competitors working with the same supplier (Lager & Frishammar, 2010). Moreover, collective technology development always involves the challenge of distributing property rights (Paasi et al., 2010). In cases where the partners are "active within the same industry the risk that they will deploy the co-owned knowledge for similar purposes is higher … [and] could jeopardize value appropriation" (Belderbos et al., 2014, p. 843). Earlier research has mainly highlighted that companies recognize knowledge leakage as an issue during

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[21] Unless limited capacities make it inevitable to shift development work to the external partner in order to temporarily tap into external resources and competences (Lichtenthaler & Lichtenthaler, 2009; Rönnberg-Sjödin, 2013).

[22] As explained at earlier stages, the content that the technology processes is unique internal knowledge and is considered more confidential than the technology itself.

the operation of new technology (Lager & Frishammar, 2010, p. 713; Rönnberg-Sjödin & Eriksson, 2010). The results in this study, however, show that for proprietary core technology the relevant knowledge is embodied in the technology itself and restricting external access is therefore imperative to protecting process innovation prior to implementation or operation, that is during the development of new technology.

6.6.2 Limited external contributions to organizational change

Organizational change presupposes an understanding of the existing organization. The reports from all the task forces, however, suggest that external partners typically have limited knowledge of internal processes, structures, culture, and interdependencies. It is well documented in the literature that organization related knowledge is complex (i.e. spanning departments and functions), often tacit in nature, and built through experience over an extended period of time (Birkinshaw et al., 2008). It is, therefore, not feasible for the task forces to convey all organizational knowledge to external partners. The results in the present study suggest that an additional challenge in this regard was the poor documentation of existing structures and processes. The limited organizational insight therefore constrains external actors in their capacity to contribute to organizational change.

The results show that social uncertainty and limited acceptance of external partners make it important for the task force to assume responsibility for organizational change. During preparation change becomes more tangible and increasingly imminent to operators. As a consequence, social uncertainty emerges among the operators (Gerwin, 1988), which can have a negative effect on their attitude towards change. Such uncertainty is a critical issue because it is difficult to gauge prior to process roll-out (Carrillo & Gaimon, 2002), yet it is critical to the successful process implementation (Meyers et al., 1999). As pointed out earlier the task forces in this study considered transparent communication a key mechanism to address uncertainty. On the one hand task forces suggested that external experts provided additional credibility for the necessity of organizational change. In fact, earlier studies support the perception that managers value external more than internal knowledge (Menon & Pfeffer, 2003). On the other hand the results across all companies show that operators tend to be strongly opposed to external input[23]. These insights hint at the "not-invented-here" syndrome, which is often cited in the technology transfer and open innovation literature to describe the reluctance of companies and individuals to embrace externally developed technologies (Katz & Allen, 1982; Lager & Frishammar, 2010). The results in the present study, however, suggest that during preparation operators are

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[23] It was a typical experience among the task forces that external management consultants found particular little acceptance among internal operators, and triggered coping mechanisms such as limited provision of information, "bend-and-wait", etc.).

particularly prone to opposing externally driven changes to the organization. This is a problem because bottom-up acceptance is necessary for approval and application of new processes (Meyers et al., 1999). Against this background the findings suggest that the internal task forces are better suited to communicate organizational changes to internal operators. Despite its limited contribution towards organizational change, the interaction with external partners enabled the companies to draw conclusions about potential areas of change beyond technology modification. As at previous stages this highlights the indirect nature of external contributions towards process innovation components other than technological change.

6.6.3   Relevant capabilities for interaction with external partners during preparation

Further knowledge assimilation and transformation during preparation: During preparation the task forces in the present study assimilate external knowledge to develop a detailed understanding of the new technology (cf. Zahra & George, 2002). In contrast to the previous lifecycle stages, technological "understanding" is not limited to concept development but results from detailed applied technology development and interaction with the technology suppliers and key operators. Lewin et al (2011) label this AC routine "learning from and with partners, suppliers, customers, competitors, and consultants" (p.90). The results suggest that this may be problematic, when there is only a limited opportunity to learn from external partners, as in the case of core technology development. In this case internal technology development (internally) as well as gathering operator feedback helps the company to improve understanding, while at the same time restricting external access to critical information. The results illustrate this issue in the case of TEC, where the task force reported that it absorbed as much external knowledge as possible during the conceptual stages and primarily focused on incremental advancements to existing technologies. In any case, the general purpose of development work routines thereof is to understand and shape new information more detail to integrate it with existing knowledge.

The results show that during preparation the task forces develop the technology but also have to understand necessary organizational adaptation and potential follow-up changes in more detail. However, limited organizational insight and acceptance of external change agents constrain the potential for external contributions to organizational change. This emphasizes the central role of the task force as an intermediary to translate technological knowledge into necessary organizational adaptations. In addition to developing an increasing understanding of the technology, a task force therefore also has to be able to transform the company's existing knowledge base through the integration of knowledge that it receives from external sources (Lane et al., 2006; Zahra & George, 2002). This transformation requires routines of "transferring knowledge back to the organization" (Lewin et al., 2011, p. 90). In this context the results reveal

practices such as close interaction with the technology supplier, internal technology development, and organizational change planning, providing information to operators through different platforms, and gathering operator feedback. The desired outcome and common purpose of these routines is the generation of a transformed knowledge base within the organization that results from the combination of new and existing knowledge. Despite increasing interaction with key operators transformative learning is still limited to specific internal stakeholders at this stage. This suggests that new external knowledge is not fully absorbed during preparation as it is not yet diffused among all relevant operators.

Capabilities for physical adaptation and integration: In addition to the assimilation and transformation of new knowledge preparation also presupposes the practical ability to physically adapt technologies for the application of new process technology and achieve systemic integration with the existing organizational context (Robertson et al., 2012). In this context the practices that this study documents indicate that companies start applying knowledge during preparation. The results show that task forces may provide technology suppliers with requests for further technological modifications or carry out modifications internally based on the knowledge absorbed during the conceptual stages (in case of core process development) to achieve a fit with the structures, processes, skills, expectations, and requirements that make up the existing organization. At the same time the companies in the present study plan and coordinate organizational change and provide information to operators through different platforms. The common purpose of these practices reflects the deployment of adaptive and integrative capabilities during preparation (Robertson et al., 2012). Nevertheless, the new knowledge is not yet put to commercial use, as the new process is not yet in operation. Knowledge exploitation does therefore not yet occur (Cohen & Levinthal, 1990; Lane et al., 2006; Zahra & George, 2002).

Enabling external partners during preparation: The results show that information exchange has to be more specific during preparation than at the preceding stages. As at previous stages, the results suggest that companies need to provide information to external partners in order to receive support for technology change. This implies that companies need to understand their own situation and appreciate the availability of relevant external knowledge sources (Robertson et al., 2012). To receive relevant answers, the companies "must know what to ask and whom to ask…" (Robertson et al., 2012, p. 830). On the one hand, this provides the opportunity to draw deeply on external knowledge. This is reflected in practices such as granting access to internal systems and working in close interaction with external partners. On the other hand, companies must convey relevant information in a way to protect critical knowledge. During the preparation stage, information is exchanged at the operational level where legal agreements do not provide sufficient protection (Slowinski et al., 2006). Routines for knowledge protection during

preparation include for example restricting external collaboration, providing only modular insight, and using dummy data. Against the backdrop, the results show that practices for enabling external partners serve the purpose to provide sufficient information if necessary but also restrict access to critical information. This presupposes an appreciation of the value of internal knowledge. Table 24 summarizes the findings relating to capability deployment during preparation in order to map out the underlying practices of the different absorptive capabilities companies deploy at this stage.

Table 24: Capability deployment: Preparation

Observable routines ➔	Common purpose ➔	AC Capabilities
Close interaction with technology supplier; Technology development (internally); gathering operator feedback	Understand new information in more detail to integrate it with existing knowledge	▪ Assimilation
Close interaction with the technology supplier; Technology development (internally); organizational change planning; providing information to operators through different platforms, gathering operator feedback	Integrate new information with existing knowledge to generate transformed knowledge base	▪ Transformation
Provide technology supplier with request for further technological modifications; Carry out modifications internally	Apply new information to integrate new technology with the organization	▪ Adaptation
Organizational change planning; providing information to operators through different platforms, gathering operator feedback	Apply new information enable integration of new technology within the organization	▪ Integration
Granting access to internal systems; close interaction with external partner; restricting external insight; providing modular insight, using dummy data	Provide external partner with information to make contributions to technological change if necessary	▪ Enablement

6.6.4 Summary and emergent themes at preparation stage

The results show that during preparation companies develop new processes in detail and prepare for implementation. Technology suppliers support technology modification and development, yet the motivation for interaction with external partners and openness differ according to the type of process a company develops. Direct external contributions to organizational change and systemic integration remain limited (see Appendix 10: Relationships

between different levels of abstraction). The main emergent themes can be summarized as follows:

- **Theme 3.1: Differences in motivation and openness towards technology suppliers exist between enabling and core processes during preparation:** In the case of enabling processes the technology supplier takes responsibility for technology development. This allows the task force to tap into external capabilities. In addition, the task forces seek to learn from external vendors by interacting closely with them. This serves the purpose of enabling the task forces to communicate technological change to operators and to configure and maintain the new technology independently during and after implementation. The involvement of external partners is limited in the case of technology development for core processes. The results suggest that companies develop technology internally in order to protect the knowledge that goes into and results from technology development.

- **Theme 3.2: External contributions towards organizational change and systemic impact remain limited during preparation:** While external partners contribute to technological change during preparation, their contributions towards organizational change planning are marginal, due to the limited insight and acceptance of external actors. Nevertheless, external input enables the internal task force to develop organizational change and plan for process innovation components other than technological change.

- **Theme 3.3: Practical adaptation occurs in addition to further assimilation and transformation during preparation:** To benefit from the information and support of external partners the companies deploy capabilities to assimilate and transform knowledge within the company and to prepare for the exploitation of the new technology in the implementation of a new process. In addition to knowledge transformation and assimilation, the deployment of practical adaptive capabilities becomes necessary during preparation. Finally, the results suggest that companies deploy the ability to enable external partners with more specific knowledge or deliberately restrict external insight to protect confidential knowledge.

6.7   Lifecycle stage 4 – Installation: Results

6.7.1   Framework category 1: Process innovation components (PIC)

Table 25 provides an overview of the sub-categories and their content relating to the process innovation components during the installation stage, as well as references to the case from

which relevant evidence was drawn. The following sections outline these contents in more detail.

Table 25: Category: Process innovation components (PIC) - Installation

Sub-category	Content	Case reference
PIC-4.1: Further adaptation during installation	Further mutual adaptation can be necessary	ALL
	"Good-enough" solutions may have to be accepted if there are limited resources for change	BMW; KNORR; TKMS; ZF
	Further adaptation or postponing implementation are unavoidable if remaining misalignments impede core operations	ALL
	Address misalignments by adjusting operators' skills and expectations	ALL
PIC-4.2: Technology installation and handover to operators	Technology is installed, configured, and handed-over to operators	ALL
	Providing technology training to shape operators' expectations and developing their capabilities to achieve compatibility	ALL
	Limited resources to provide training in large and broad scope projects companies	BMW; ZF
PIC-4.3: Organizational change and addressing social uncertainty	Confrontation with organizational change causes uncertainty among operating base	BMW; KNORR; TKMS; ZF
	Acceptance among operators necessary to exploit new process	BMW; KNORR; TKMS; ZF
	Structural change more difficult to implement than change to existing work processes	BMW; KNORR; TKMS; ZF
PIC-4.4: Systemic integration management	Systemic integration is a key objective during this stage	ALL
	Ease of systemic integration is a result from systemic impact assessment during earlier stages	ALL
	Seamless integration is necessary (at all costs) for process that affect core operations	TEC; (BMW)*

BMW provided additional, corroborating evidence for this content

PIC-4.1: Further adaptation during installation: All the task forces that participated in this study reported that despite preparatory activities further adaptation often became necessary during installation. Nevertheless, BMW, KNORR, TKMS, and ZF pointed out that typically only limited resources (e.g. funding, time, and workforce) were available at this stage, which impeded the scope for further adaptation. *"We often do not have enough funds to perform such change requests at such a late stage. It can happen that we have to accept solutions that are "good-enough", solutions that work okay but need to be improved in follow-up projects. In core processes such as production something like this would, however, be very unlikely. If you know that there is a critical issue in a core process, then we need to invest right away" [R3-I1].* The results clearly show

that this approach is only feasible if the remaining misalignment does not affect the core operations of the company. TEC in particular emphasized that the most important issue during installation was to keep production running. The task force members in TEC explained the following: *"We cannot accept an inferior solution in the area of our core processes. We have to really just go ahead and have to ask the steering committee or even the top management for more money. We cannot afford to pay the costs of an inferior solution. In the industry, in which we operate, we cannot accept any quality risk. The follow-up costs and the reputational issues would be too significant. Changes at this stage are hard, they are unpleasant. But accepting an underperforming solution is much worse" [R23-I1].* To overcome misalignments during installation, all companies in the present study reported that it was often only necessary to form the skills and expectations of the operators. All task forces agreed that communicating the new process to internal operators involved the provision of training and seminars in order to facilitate support for hands-on experience, and the distribution of information material about the new process. KNORR and ZF suggested that training for operators often suffices to overcome misalignments between the new process and the operators' expectations and capabilities. *"That means we may have to make further adjustments to the solution but quite often providing sufficient training suffices" [R8-I1].*

PIC-4.2: Technology installation and handover to operators: All companies in the study agreed that it was typically only necessary to configure rather than modify new technology.[24] The task forces across all cases agreed that the extent to which the broader operating base adopted new technology as intended by the task force was the most critical determinant of successful technology introduction. The main problem reported by all the companies was the operators' uncertainty about their own ability to work with a new technology. This can lead to coping mechanisms. *"Of course they claim that there are issues with user-friendliness, partially missing functionality, or generally the ease of use" [R1-I2].* All task forces thus stated that it was imperative to provide communication and extensive training. The following statements from TEC interviewees reflect the importance of training. *"Our task during handover is to make our stakeholders understand the application and the implication of the new technology, and how they can benefit from it" [R21-I1]."They need to understand good and bad practice. They may need to obtain new certifications. If we do not do that very well, then this can have significant consequence for quality or costs" [R23-I1].* The task forces thus considered it necessary to have an adequate support infrastructure (e.g. training, hotlines, etc.) in place to provide training and ad-hoc

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[24] Configuration means that all necessary functions exist but need to be calibrated correctly. Technology configuration refers to calibrating the technology's existing functions to perform specific tasks. For example, particular software has the functionality to store and provide data. In order to use the software it is necessary to be calibrated by specify the location of data sources and recipients, etc. Similarly, a welding robot has the functionality to weld according to different specifications, but needs to be calibrated to adhere to these specifications.

problem solving. As a result, all cases showed that technology roll-out typically required substantial capacities (especially in terms of manpower) to install technology, provide training to operators, and solve emerging problems ad-hoc. A common thread to the reports by BMW and ZF, who reported on the introduction of processes across global operations, was the insufficient capacity to communicate technological change to a large number of operators in a timely manner. *"During the introduction it is necessary to provide training. Supervisors are often not very happy when their staff is sent to training or used in a training function, due to the lack of productive work during that time. Providing training always requires immense capacity" [R27-I2].* The experiences by TEC and TKMS, in contrast, related mainly to the introduction of new technology in a single operations facility and in the case of KNORR in a single facility at a time. In these contexts, training capacity was not mentioned as an issue.

PIC-4.3: Organizational change and addressing social uncertainty: The task forces in BMW, KNORR, TKMS, and ZF explained that during installation organizational change became inevitable reality to the broader operating base. "*Now we carry out implementation. This is always difficult. People realize that change will affect them but not necessarily how exactly. This uncertainty can significantly hamper the success of implementation" [R16-I2].* ZF, further, pointed out that lacking acceptance of organizational change impeded process standardization on the corporate level, which created significant inefficiencies. *"We are often not in a position to implement the processes in the way we would like to. Standardization and consistency across different departments is a big issue. The people typically try to avoid changes to how they perform their work, even if that would make many processes way more efficient. This creates a lot of wasted efforts. The central problem is the difficulty of organizational change" [R27-I2].* While top-management support was considered important to drive organizational change, KNORR and ZF particularly highlighted the importance of fostering acceptance among operators. According to the experiences by the task forces in BMW, KNORR, TKMS, and ZF the opposition to organizational change was particularly pronounced when it related to roles, relationships, status, and power (i.e. structural change).

PIC-4.4: Systemic integration management: The results from all companies in this study show that the integration of a new process with the organizational system is a key objective during the installation stage. According to the task forces' experiences, the success of integration largely depends on the preparations carried out at earlier stages. Nevertheless, all reports in this study indicate that the systemic impact of a new process only truly becomes evident during installation. Therefore, the task forces suggested that further adjustments to technology or organization may become necessary to fully enable a new process. In this respect, the task force in TEC repeatedly stressed the importance of resolving any potential negative impact on the production system immediately. *"If we identify issues of integrating new processes within our*

existing operations before implementation we cannot accept the new process. In such cases we really have to make further investments" [R23-I1]. However, the task forces in BMW, KNORR, TKMS, and ZF, who reported on the introduction of enabling processes, suggested that in some cases change had to be postponed to follow-up projects. *"Sometimes we have to just roll-out a solution and immediately make plans for a follow-up project after the initial rollout, where we can address remaining problems" [R8-I1].*

6.7.2 Framework category 2: Motivation for interaction with external partners (MOT)

Table 26 provides an overview of the sub-categories and their content relating to the motivation for interaction during the installation stage, as well as references to the case from which relevant evidence was drawn. The following sections outline these contents in more detail.

Table 26: Category: Motivation (MOT) - Installation

Sub-category	Content	Case reference
MOT-4.1: Additional capacities for technology implementation	Using supplier's skills for quick installation of new technology	BMW; KNORR; TKMS; ZF
	Gaining support for ad-hoc problem solving	ALL
	Accessing temporary capacities for supporting the provision of technology training	BMW; ZF

MOT-4.1: Additional capacities for technology implementation: All the companies which discussed the introduction of externally acquired standard solutions reported that their typical motivation for interaction with external partners during installation was to gain additional capacity. *"Yes, if we consider the topic of IT solutions for enabling processes, then clearly more work is shifted towards the external partner" [R2-I2].* BMW and ZF, for example, explained that they worked with external partners in order to access additional capacities or capabilities that are not required internally, as the following excerpt clarifies. *"It's simply the huge amount to of work. Our internal capacity does not suffice for that. Question: So working with external partners at this stage is actually mostly about additional capacities? Answer: At the end of the lifecycle it's simply a matter of capacity, not more and not less. While it's all about knowledge transfer at the beginning, it is all about capacities at the end of the innovation project" [R29-I2].* All companies clearly emphasized that they had to possess sufficient internal knowledge of the new technology to perform configuration internally. *"Our internal people, the ones that were involved in the project would be able to perform these tasks internally. But we generally do not have the necessary capacities given the large number of operators that we have to address" [R28-I2].* KNORR, for example, reported using technology suppliers for the physical installation of new technology because this capability was not needed internally. It is cheaper and faster to let the external

partner carry out this activity. There was, however, no need for KNORR to use the external partner to add data into the new system. *"The external partner then only takes responsibility for installing the technology, from a physical perspective, from a hardware perspective. We are responsible for the configuration of the technology and for making the final adjustments to the process" [R7-I1].* TEC also reported to carry out installation internally. Nevertheless, all companies agreed that technology or component suppliers could provide assistance for ad-hoc problem solving.

6.7.3 Framework category 3: Openness during installation (OPN)

Table 28 displays the content relating to the emergent sub-categories of openness during the installation stage, as well as references to the case from which relevant evidence was drawn. The following sections outline these contents in more detail.

Table 27: Category: Openness (OPN) - Installation

Sub-category	Content	Case reference
OPN-4.1: Structure of work responsibility distribution	Installation or support for installation provided by external partner but closely observed by the task force	ALL
	Configuration remains an internal responsibility	ALL
	Conjoint training development with external partner	BMW; ZF
	Technology training can be delivered by external partner	BMW; ZF
	Work responsibilities can be clearly specified and defined	ALL
	Task force can observe and evaluate performance by external partner	BMW; KNORR; TKMS; ZF
	Intensity can be high in frequency but is very formal and not in-depth	BMW; KNORR; TKMS; ZF
OPN-4.2: Knowledge sharing and protection	Confidential information necessary to perform configuration task	ALL
	Restrict external access to confidential information	ALL
	Limited, well-defined insight and process integration as protection mechanism	BMW; KNORR; ZF
	Access to less critical data may be granted	KNORR

OPN-4.1: Structure of work responsibility distribution: It emerged from all the companies that the selected technology suppliers was typically responsible for the physical technology installation. The reports also show that technology partners have to coordinate all activities with the task force and are constantly monitored by internal members of the company while performing the installation task. BMW, KNORR, TKMS, and ZF stated that the finalized process

description makes it possible to specify the tasks external partners have to perform during the installation stage. *"At this stage we have specified the solution in detail and we can clearly specify what we will introduce and how we want to introduce it" [R2-I2].* An interviewee from ZF added *"Because our requirements and expectations can be clearly expressed, the interaction during installation is very structured and formal" [R32-I2].* The task forces clarified that only in exceptional cases, where significant technological changes and ad-hoc solutions became necessary during installation, would the interaction with external partners become relatively unstructured and informal. However, the results suggest that generally the frequency of interaction with the external partners tends to be high, yet not particular in-depth. *"Technically, of course, the supplier was primarily responsible only to get the system up and running here" [R13-I2].* Moreover, the companies that use external partners to support training (BMW and ZF) reported that the limited organizational insight of external partners was a key challenge. To address this issue, the task forces in BMW and ZF typically develop training conjointly with the external partner. The communication of organizational change and addressing potential resentment against such change, however, remained an internal responsibility in all companies. In cases where sufficient internal capacity was available to educate operators about new technology (KNORR, TKMS, and TEC), the task forces performed training internally. KNORR, for example, stated that the internal task force was always in a better position to provide training, *"…because the internal taskforce will always have a better understanding of the company" [R2-I2].*

OPN-4.2: Knowledge sharing and protection: The reports by all companies in this study indicate a strong focus on knowledge protection during installation. The results show that TEC already aims to reduce external involvement during preparation in order to protect internal knowledge. During installation knowledge protection becomes a managerial challenge for the other companies as well. Technology configuration, in terms of calibrating it to work with actual data or within a productive setting, requires knowledge about processes and insight into internal data rather than extensive capacities. Because the new process needs to work in a real operating environment, the use of "dummy data" as at earlier stages is no longer feasible during installation. BMW, TKMS, KNORR, and ZF, therefore, explicitly restrict the access for external partners. In this respect, the results from all companies in this study showed that configuration is the responsibility of the internal task forces. *"Whereas we use development systems during preparation, we obviously have to work within the real systems environment during installation and because of that we strongly restrict external access" [R28-I2].* Nevertheless, KNORR, BMW, and ZF also suggested that the limited snapshot that external partners glimpsed did not reveal sufficient insight into the integrated operations within the company to impede the appropriation of a new process. In this context a BMW interviewee stated: *"I believe that it is very difficult to*

copy, for example, the concept of modular production as BMW does it, one to one. The real challenge is the detailed development and the implementation" [R1-I2].

6.8   Lifecycle stage 4 – Installation: Discussion

The results presented installation as the conclusion of the innovation lifecycle. During installation companies ultimately commercialize process innovation within the real operating environment. This involves technology installation, training, the introduction of organizational change, and systemic integration. The companies in the present study regarded communication as a critical enabler of successful process innovation. In this context, the results show that the task forces work with external partners for technology installation and communication, while technology configuration and organizational change communication remain internal responsibilities. Furthermore, knowledge protection and restricting external insight becomes a more relevant managerial challenge for the companies reporting on enabling processes than at earlier stages. The findings also suggest that accessing additional capacities is the main driver for working with external partners during installation. The following sections discuss these insights in further detail.

6.8.1   The involvement of technology partners during installation

The findings in the present study suggest that sufficient capacity is necessary for prompt process installation. This is important to achieve rapid ramp-up, for example (Hayes et al., 2005). As the cases of BMW and ZF show, lacking capacity can be a particular challenge in broad scope projects. External partners may thus be important to provide temporary capacities to complement a company's internal capacities. Yet, the results show that external partners also support technology installation in narrow scope projects (KNORR; TKMS) despite the companies' sufficient internal capacities. Technology installation refers to delivering and physically putting new technology into place (e.g. connecting it with other technologies or within a production or information system). However, internal members of the company do not perform such tasks very often. Given the infrequent nature of installing new technology, the installation, as opposed to the operation of new technology, is not an ability the company needs to internalize. Technology suppliers, in contrast, possess the experience and practice of technology installation, especially for standard solutions (cf. Flowers, 2007). As a result, the installation of technology is an opportunity to tap into a skilled external workforce to support or complete the installation task. The present study, therefore, concurs with the findings of earlier studies that external partners can provide substantial support process installation activities (Athaide et al., 1996; Lager & Frishammar, 2010; cf. Rönnberg-Sjödin et al., 2011; Rönnberg-

Sjödin, 2013). However, the results of the present study go further by clarifying that working with external partners during installation relates to accessing temporary capacities or capabilities that are not needed internally. This calls into question to what extent installation is actually a stage of "extreme learning" from external partners, as proposed, but not empirically documented, by Lager and Frishammar (2010). While companies certainly learn more about the technology as they begin to use it, the results of the present study suggest that the motivation to learn from external partners is stronger at earlier stages of the innovation lifecycle, while installation mainly focuses on external support for the execution of clearly defined tasks which build on previously prepared work and restrict external access to internal systems.

The results reveal a preference for internal technology configuration. As technology is ultimately introduced into the real operating environment, configuration requires access to potentially confidential product or production related data and it is no longer an option to use "dummy data". At previous lifecycle stages companies could work with external partners on the development of enabling processes without revealing confidential information. During installation, however, companies face the challenge of managing knowledge protection by performing critical tasks internally and restricting access for external partners; thus converging with the patterns documented for core process development. This insight also highlights the interconnectedness of the different lifecycle stages, as the ability to configure new technology draws on the task forces' engagement with technology development at earlier stages (Frishammar et al., 2012; cf. Lu & Botha, 2006). Furthermore, the present results suggest that knowledge protection is important prior to the operation of a new process, while earlier literature on open process innovation primarily highlighted the role of knowledge protection during operation (Rönnberg-Sjödin & Eriksson, 2010). Rönnberg-Sjödin and Eriksson do not provide sufficient background information on the cases they study to clearly identify why the companies in their study were not concerned about knowledge protection during operation but not during installation and start-up. They argue that "in many cases the equipment developed is not of any use to the competitors, since they have very different processes" (p. 669). The present study finds similar ideas among the task forces (e.g. BMW; KNORR), namely that well-integrated processes are company-specific and difficult to copy. Yet, the results in the present study go further and point out that internal stakeholders consider proprietary technology as well as product or production related knowledge relevant to their company's competitive advantage. Therefore, the task forces carry out activities requiring access to such confidential knowledge internally, even at stages prior to operation. In summary, the present study substantiates the importance of external support during process installation. Yet, it documents a much more conservative integration of external partners during installation than earlier literature suggests (Lager & Frishammar, 2010; cf. Rönnberg-Sjödin et al., 2011; Rönnberg-Sjödin, 2013). The

results suggests that restricting access to the operating environment and to confidential information required during installation is the main rationale behind working with external partners only for additional capacities and capabilities that are not required internally.

The relevance of addressing the broader operating base was a key theme during the installation stage. Preparation allows companies to develop theoretically well-aligned processes and is likely to have a positive effect on process installation (Tyre & Hauptman, 1992). Installation, however, differs from earlier lifecycle stages as it confronts the broader operating base with new technology and organizational change. This increases the social uncertainty and spurs resentments among operators (cf. Gerwin, 1988). Yet, bottom-up acceptance is critical for process implementation (Meyers et al., 1999). The literature suggests that due to time pressure, technological and organizational complexity, and limited budgets not all misalignments can be anticipated prior to implementation (Von Hippel & Tyre, 1995; Leonard-Barton, 1988). The findings in the present study, however, show that substantial technological or organizational changes during installation are often not viable due to resource constraints. Instead the results suggest that communication and training are the mechanisms by which task forces shape operators' attitudes in order to achieve compatibility between the new process and the operators' skills and expectations. The present study thus concurs with earlier findings that communication is necessary to achieve acceptance and address uncertainties (cf. Cantamessa et al., 2012; Leonard-Barton & Deschamps, 1988; Meyers et al., 1999; Piening & Salge, 2015; Tyre & Hauptman, 1992; Voss, 1992). In particular, communication is necessary to "motivate employees to use an innovation consistently and appropriately" which task forces in turn expect to lower the need for technological or organizational change and make it more likely to "establish effective operational routines for its continuing use" (Piening & Salge, 2015, p. 83). In contrast to earlier stages, however, communication becomes more challenging during installation because the task force has to reach the broader operating base rather than selected key users.

The evidence in the present study corroborates earlier studies showing that technology suppliers support communication during the installation of new processes (cf. Athaide et al., 1996; Lager & Frishammar, 2010; Meyers et al., 1999; Rönnberg-Sjödin et al., 2011; Rönnberg-Sjödin, 2013). Rönnberg-Sjödin et al. (2011), for example, find that "equipment suppliers usually hold extensive educational programs for operators and maintenance personnel" (p.233). Nevertheless, the evidence in the present study refines these insights and suggests that external support for communication is mainly necessary to cope with limited capacities (see BMW and ZF). Without external support, the lack of internal capacities may impede process implementation, as the internal task force cannot introduce new processes with sufficient support for operators to prevent conflict and unintended operations (Meyers et al., 1999). In the cases where sufficient internal capacity was available to educate operators (KNORR, TKMS, and

TEC), the task forces performed training internally. While TEC may also restrict external access due to the proprietary nature of the technology itself and TKMS has to comply with strict data protection given its military status, the task force in KNORR explicitly highlighted their superior internal capabilities for the provision of training.

The relevance of internal capabilities for the communication of change is also reflected in the finding that external partners only supported the communication of technological change. The cases in this study are characterized by large, complex structures and production systems with limited malleability which makes it more difficult to introduce organizational change (cf. Majchrzak et al., 2000) (see Appendix 1: Characteristics of large companies). Organizational change involves tacit knowledge (Birkinshaw et al., 2008). Moreover, the task forces in the present study suggested that there was a resistance among key stakeholders to adopt changes to internalized structures and processes that have developed over time. Addressing uncertainties and responding to tacit expectations and requirements requires an in-depth understanding of the company as well as empathy for colleagues affected by process change. As a result the findings clearly suggest that communication of organizational change is an internal responsibility.

6.8.2 Relevant capabilities for interaction with external partners during installation

Early exploitation, further adaptation, integration, assimilation, and transformation: The transition from technology research and development to application and operation is a necessary condition of technological innovation (Crossan & Apaydin, 2010; Lichtenthaler & Lichtenthaler, 2009). Likewise, the commercialization of new knowledge to achieve organizational objectives is a central component of the absorptive capacity construct (Cohen & Levinthal, 1990; Zahra & George, 2002). The installation stage as presented in this study, documents the initial exploitation of previously accessed, assimilated, and transformed knowledge for the initial start-up of new processes (cf. Lane et al., 2006; Lichtenthaler & Lichtenthaler, 2009; Robertson et al., 2012).

In order to begin knowledge exploitation, companies need the ability to introduce the technology and disseminate new knowledge internally (Zahra & George, 2002, p. 194). The results suggest that this involves practices such as technology configuration; providing technology training, and communicating organizational change. This serves the purpose of implement process within broader organizational system and points to the deployment of integrative capabilities (Robertson et al., 2012). In contrast to earlier stages, installation requires the practical execution of integration within a real operating environment, and usually only minor further assimilation of external knowledge and adaptation of new technology.

Nevertheless, technology configuration and developing training with partners also serves the purpose of further improving the understanding of new knowledge, which points to further deployment of assimilative capabilities. In contrast to the early lifecycle stage these are influenced by the practical nature of performing change. As the companies perform the routines they may also solve unanticipated technological issues, thus deploying adaptive capabilities.

Knowledge exploitation requires communication with operators to "share relevant knowledge among members of the firm in order to promote mutual understanding and comprehension" (Zahra & George, 2002, p. 194). This involves routines of "sharing knowledge and superior practices across the organization" (Lewin et al., 2011, p. 87). The results in this study, for example, document the provision of training as a key practice for knowledge dissemination among operators. Knowledge diffusion also indicates that further transformation takes place during installation, as new knowledge is presented to the broader operating base (cf. Lane et al., 2006). In contrast to the preparation stage, new internal knowledge resulting from the acquisition of external knowledge and integration with prior internal knowledge is no longer restricted to the development environment. Instead, the objective of installation is to roll out the new process to full scale and to all operators rather than only a select few.

While external capacities can support clearly defined technology installation and communication tasks, the results document how companies exploit previously absorbed knowledge to configure the technology and leverage internal knowledge to communicate organizational change. The insights of the present study are in line with Cohen and Levinthal (1990), when they state that: "communication systems may rely on specialized actors to transfer information from the environment … and translate the technical information into a form understandable to the research group" (p.132). In this respect, the results re-emphasize the relevance of task forces as intermediaries between external partners and the internal operating base. By enacting these practices outlined above the task force effectuate the initial operation of technological and organizational change to start commercial application of new knowledge and therefore the exploitation of the new knowledge.

Enabling partners and protecting knowledge: The results show that the companies in this study assign specific, clearly defined tasks to external partners (e.g. technology installation, training provision). Defining tasks, assigning external partners, monitoring, and evaluating the task performance presupposed a sufficient internal understanding of the new process and the activities and challenges involved in performing specific tasks during installation. Likewise, the external partner needs to be enabled and provided with sufficient information to perform tasks. This is, for example, reflected in practices such as conjoint training development. Moreover, KNORR suggested that external partners could access internal systems to provide support for

ad-hoc trouble shooting when the data were not confidential. When task performance requires access to more critical data or proprietary technology, companies may seek to shield such data from external partners by maintaining the configuration task internal, as the cases of TKMS and ZF showed. Such practices point towards the relevance of an ability to identify the relevance and value of internal knowledge and to make it accessible to the external partner if necessary. At the same time this requires the ability to carry out work internally if the need to protect knowledge means that they cannot grant external partners access to it. In sum, these insights point out that the exploitation of previously absorbed knowledge is necessary to specify tasks for external partner and restrict external access to internal knowledge if necessary. Table 28 summarizes the findings relating to capability deployment during installation.

Table 28: Capability deployment: Installation

Observable routines ➔	Common purpose ➔	AC Capabilities
Technology configuration; develop training with partners	Further improving understanding of new knowledge	▪ Assimilation
Provide technology training; Communicate organizational change	Diffuse new knowledge internally to alter broader knowledge base	▪ Transformation
Technology configuration; Provide technology training; Communicate organizational change	Installation and training to implement new technology and potentially discover further issues	▪ Adaptation
Technology configuration; Provide technology training; Communicate organizational change	Actual introduction of technological and organizational change to implement process within broader organizational system	▪ Integration
Clearly define tasks for the external partner; perform tasks internally if necessary; Train operators to work with new process	Initial operation of technological and organizational change to start commercial application of new knowledge	▪ Exploitation
Clearly define tasks for the external partner; Develop training with partners	Specify tasks for external partners and restrict external to internal knowledge base access if necessary	▪ Enablement

6.8.3   Summary and emergent themes at installation stage

The objective of installation is process roll-out and systemic integration within the company as prepared at the earlier stages of the innovation lifecycle. The results show that a key issue during installation is the uncertainty among operators. However, "bottom-up" acceptance is a necessary condition for successful process installation (Meyers et al., 1999). The evidence suggest that to cope with this issue new technology and organizational change have to be communicated to the operators of the new process, in order to achieve acceptance, compatibility, prevent unintended coping mechanisms, and ultimately to exploit the relative

advantage of the new process and its new technology. In this context, the results show that the companies in the present study use external partners to support installation through temporary capacities and capabilities that the companies do not need internally (see Appendix 10: Relationships between different levels of abstraction). The main themes that emerge from the results are the following:

- **Theme 4.1: External contributions are relevant for capacity and temporarily necessary capabilities during installation:** Process implementation may require significant capacities to achieve seamless introduction of new processes without disrupting existing operations. This can be an issue under conditions of limited workforce, funding, and time. Against this backdrop, a company's motivation to work with external partners mainly relates to accessing additional, temporary capacities and capabilities it does not normally require internally. Such additional capacities are particularly necessary for the physical installation of new technology and the provision of training to large numbers of operators.

- **Theme 4.2: Converging results for relevance of knowledge protection and for work responsibility distribution for core and enabling processes during installation:** The installation stage is characterized by the transition of technologies from a development setting to real operations and the processing of real data. Access for external partners to internal knowledge is more restricted than at previous stages. The concern for knowledge protection increases both for new enabling and core processes. Configuration therefore remains an internal responsibility in order to protect confidential data. Similarly, the communication of organizational change remains with the task force to leverage internal knowledge advantages.

- **Theme 4.3: Exploitation, integration, and further transformation during installation:** During implementation task forces focus more strongly on the internal application of new knowledge. This means that companies start exploiting knowledge generated at earlier stages. Exploitation is necessary to diffuse knowledge internally, to enable external partners, and to protect internal knowledge where necessary. Yet, further knowledge transformation occurs from the perspective of the operating base within the company as knowledge is disseminated to an increasing number of operators.

7 General discussion and construct development

This chapter provides a general discussion of the study's findings from an aggregate perspective. This addresses the study's second unit of analysis. The discussion links together the key themes that were identified within the individual lifecycle stages and develops theoretical constructs of open process innovation. Specifically, the chapter comprises a discussion of the external contributions to technological change, methodological guidance by management consultants, the nature of further external contributions, and capability deployment for open process innovation. Table 29 shows how the themes in the different stages feed into the emergent constructs.

Table 29: Constructs and underlying themes

Constructs		Themes
1	External contributions to technological change	←	1.1; 2.1; 3.1; 4.1; 4.2
2	Methodological guidance by management consultants	←	1.2; 2.2
3	The nature of further external contributions	←	1.1; 1.3; 2.1; 2.3; 3.1; 3.2; 3.3; 4.1; 4.2, X
4	Capability deployment for open process innovation	←	1.3; 2.3; 3.3; 4.3

See Appendix 10: Relationships between different levels of abstraction) for full overview of relationships between categories, themes, and constructs

7.1 External contributions to technological change

The results in the preceding chapter documented a variety of motivations for the interaction with external technology experts. The results also show that the motivation to work with external technology partners changes between the lifecycle stages and may differ for the development of enabling and core processes. The following sections elaborate on these insights from an aggregate perspective, i.e. throughout the entire lifecycle.

7.1.1 Basic motivations for interaction with external partners

The present study documents key motives for seeking external contributions to technological change throughout the innovation lifecycle. The external contributions sought by the companies in the present study largely reflect the insights from earlier literature on the role of technology suppliers in technological process innovation (Table 30).

Table 30: Mapping basic motivations for interaction

Basic general motivations for interaction with external technology partners			
Ideation	**Adoption**	**Preparation**	**Installation**
Gather technological information to fertilize ideas	Access to technological information as motivation for interaction with technology suppliers	Obtain external support for technology development	Gain additional capacities for technology implementation and provision of training
Obtain methodological guidance	Obtain methodological support during concept development and decision making		

The discussions of the individual lifecycle stages also show how the findings compare to recent studies on open process innovation from a lifecycle perspective (Lager & Frishammar, 2010, 2012; Rönnberg-Sjödin et al., 2011; Rönnberg-Sjödin & Eriksson, 2010; Rönnberg-Sjödin, 2013). Mapping external contributions to technological change throughout the innovation lifecycle clarifies how the motivation to work with external partners relates to the activities, outputs, and challenges that characterize the different lifecycle stages. However, such insights on their own remain largely descriptive and potentially case-specific, which is a key limitation of earlier studies as was shown during the earlier chapters in this study. The initial mapping of external contributions can nevertheless provide the basis for a more conceptual perspective on the motivation to interact with external partners for technological change. The following sections provide further abstraction of external contributions to technological change.

Proposition 1: *The motivation to seek external technology contributions to process development and implementation changes at different lifecycle stages and depends on the activities, outputs, and challenges of technological change at each stage.*

7.1.2 Different forms of external contributions

7.1.2.1 Capability and capacity contributions

The results of the present study show that absorbing knowledge and developing new capabilities are key motivations for the interaction with external partners during ideation, adoption, and preparation. During installation, the motivation largely shifts towards accessing additional workforce and resources to carry out specific tasks in case of lacking internal capacities or when the necessary capabilities are not needed internally. The results thus suggest that external contributions towards technological change, as documented in the present study, can broadly be grouped into capability and capacity contributions. Companies seek *capability contributions* when they seek interaction with external partners to absorb knowledge and

develop capabilities that are not yet available but considered necessary to possess internally. Companies seek *capacity contributions* when they are motivated to interact with external partners to access additional workforce or resources to carry out specific tasks, although the necessary capabilities to perform these tasks are available or when they are not needed internally.

The distinction between capability and capacity contributions is similar to Wagner and Hoegel's (2006) distinction between *"know-how projects"* and *"capacity projects"* in the context of supplier integration for new product development. Yet, the lifecycle perspective applied in the present study shows that both forms of contributions are necessary during process innovation projects. Wagner and Hoegel (2006), in contrast, refer to projects and not individual stages. From a task force's perspective, access to external capabilities is necessary to understand and develop new technologies and access to temporary capacity is necessary to implement a new process. Furthermore, the results show that despite their analytical distinction, the different forms of contributions are not mutually exclusive. Instead, they are closely interlinked and may appear conjointly. In the present study, this was particularly evident during preparation. The results indicate that the companies engage with external partners for component development and technology modification during preparation. The interaction with the external partner helps the task force develop new capabilities internally. At the same time, the external partner temporarily provides additional workforces to carry out specific development tasks.

The distinction between different forms of contribution enables a more precise discussion of open process innovation. Earlier studies have, for example, documented the collaboration between equipment buyers and suppliers during installation, in which suppliers teach companies the application of new technology (e.g. Rönnberg-Sjödin, 2013). The present study agrees that external contributions support installation in different ways. However, the results suggest that these contributions are mainly capacitive in nature, while companies develop relevant internal knowledge and capabilities at earlier stages. During process installation and operation, the companies apply new knowledge internally. Independent internal application is necessary to prevent a loss of capabilities (Flowers, 2007) and protect access to confidential internal knowledge. The results of the present study thus reflect strategic level considerations of keeping core-competencies internal, while outsourcing less relevant activities, at the operational level (cf. Quinn & Hilmer, 1994).

7.1.2.2   Conceptual and applied capability contributions

The lifecycle perspective on open process innovation applied in the present study reveals differences in the way companies structure the interaction with external partners to obtain capability contributions. Against this background, the thesis introduces a distinction between

conceptual and applied capability contributions. Capability contributions are conceptual if external technology experts use their capabilities to help companies generate a theoretical understanding of new technology, based on the provision of information but not practical experience. Capability contributions are applied if external partners use their capabilities to provide tangible support for technological change which enables companies to develop experience-based understanding of new technology.[25]

To substantiate the distinction between conceptual and applied capability contributions, consider first the case of developing enabling processes (BMW, KNORR, TKMS, and ZF). During ideation, the companies access external capabilities by obtaining general information from various external technology experts. This enables the task forces to access relevant external capabilities and develop knowledge of potentially relevant solutions, although the external experts do not transfer any particular technology or specific information *(Conceptual contribution)*. The suppliers' technology presentations during adoption provide more specific information than during ideation and help the companies increase internal technological knowledge. Yet, the companies are motivated to access external knowledge through information and presentation rather than conjoint work activities *(Conceptual contribution)*. During preparation, however, external technology partners actively transfer tangible technology and applied knowledge through close interaction with the companies' internal task forces. In contrast to the earlier stages, this illustrates the companies' motivation to seek capability contributions through close interaction with technology suppliers and practical knowledge application *(Applied contribution)*. The new knowledge enables the companies to work largely independently during installation and only engage with external partners for capacity contributions.

A different path emerged for the case of TEC. Like the other companies, TEC seeks general information for core process innovation from external sources early on *(Conceptual contribution)*. Yet, the limited availability of relevant information on potential solutions pushes TEC to engage in early conjoint prototyping with external partners. In these collaborations the task force in TEC practically generates relevant information about new technologies *(Applied contribution)*. This knowledge lets TEC work largely independently during the development and installation of core technology and only engage with external partners if internal capacities do not suffice Table 31 summarizes displays the different contributions that the companies seek along the innovation lifecycle.

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[25] The distinction between both forms of capability contributions is analytical because even applied contributions will enhance companies' theoretical understanding of new technology. Nevertheless, it is important to discern both forms in order to disentangle the different ways of obtaining these contributions.

Table 31: Different forms of external contributions to technological change

External contributions towards technological change across the innovation lifecycle				
	Ideation	**Adoption**	**Preparation**	**Installation**
Enabling processes	Conceptual capability contribution	Conceptual capability contribution	Applied capability contribution	Capacity contribution
Core processes	Conceptual capability contribution	Applied capability contribution	Applied capability contribution (restricted) / Capacity contribution	Capacity contribution
Capability contribution	Companies seek capability contributions when they seek interaction with external partner to absorb knowledge and develop capabilities that are not yet available but considered necessary to possess internally			
Conceptual capability contribution	Capability contributions are conceptual if external technology experts use their capabilities to help companies generate a theoretical understanding of new technology, based on the provision of information but not practical experience			
Applied capability contribution	Capability contributions are applied if external partners use their capabilities to provide tangible support to technological change, which enables companies to develop experience-based understanding of new technology			
Capacity contribution	Companies seek capacity contributions when they are motivated to interact with external partners to access additional workforce or resources to carry out specific tasks, although the necessary capabilities to perform these tasks are available or when they are not needed internally			

The distinction advanced by the present thesis reaches beyond the earlier conceptualization of "know-how" projects as posited by Wagner and Hoegel (2006), which does not consider different forms of capability contributions. The distinction is relevant because it points towards different structures of interaction by which companies can obtain capability contributions. Wagner and Hoegel suggest that capability contributions involve highly intense interaction with selected suppliers in a "partnership-like relationship" (p.939), which requires time, trust, and significant information exchange. Although investments in close interaction have a positive effect on successful process innovation (Terjesen & Patel, 2014), external search also incurs substantial costs and presents companies with the challenge of the adequate allocation of limited resources (Horváth & Enkel, 2014; Laursen & Salter, 2006). Companies thus have to understand external technologies sufficiently well to make investment decisions without engaging in close partnerships at the outset of the innovation lifecycle, especially when searching from a broad range of potentially relevant knowledge sources as in the case of acquiring external standard solutions. The distinction between conceptual and applied contributions attempts to explain how companies cope with this challenge by choosing between different forms of capability contributions throughout the innovation lifecycle.

Proposition 2: *When companies engage in learning processes and aim to develop new capabilities they will seek external capability contributions. When companies have developed sufficient internal capabilities to maintain and exploit new knowledge and technology they will mainly seek capacity contributions from external partners.*

7.1.3   Configurations of openness and different forms of external contributions

The results show that the motivation for interaction changes throughout the innovation lifecycle. The activities, desired outputs, and problems at any given lifecycle stage inspire different motivations for interaction with external partners. The previous insights link the motivation for interaction to the openness for external technology contributions. The results provide empirical evidence that companies dynamically adjust openness throughout the innovation lifecycle. More specifically, the results show that search breadth decreases throughout the innovation lifecycle. At the same time, search depth increases from ideation to preparation, before it decreases to weak levels during installation (Table 32).

Table 32: Open process innovation for technological change

Development of enabling processes: external contributions towards technological change				
	Ideation	**Adoption**	**Preparation**	**Installation**
External Contribution	Conceptual Capability	Conceptual Capability	Applied Capability	Capacity
Information availability	Available	Available	Limited	Available*
Relevance of knowledge protection	Low	Low	Low	High
Search breadth	Broad	Medium	Narrow	Narrow
	Various external technology experts Necessary to capture the breadth of relevant available information and potential solutions	Selected group of potential technology suppliers Narrower search necessary to focus on pre-selected solutions	Selected technology supplier Exclusive focus necessary to develop in-depth technological knowledge	Selected technology supplier Obtain temporary capacities from knowledgeable expert for specific tasks
Search depth	Weak	Medium	Strong	Weak*
	Weak interaction at various occasions Limited requirements specification and costs involved in broad search impede depth of interaction	Medium interaction during technology presentations Providing expectations and requirements to obtain more specific information on pre-selected ideas	Collaboration and frequent coordination for detailed technology development Development does not require access to confidential data	External support for technology installation (and training provision)** Ambition to restrict external access to confidential information

(continued on next page)

Development of core processes: external contributions towards technological change

	Ideation	Adoption	Preparation	Installation
External Contribution	Conceptual Capability	Applied Capability	Applied Capability (restricted)	Capacity
Information availability	Limited	Limited	Limited	Available*
Relevance of knowledge protection	Medium-Low	Low	High	High
Search breadth	Broad-Medium	Medium	Narrow	Narrow
	Initial various external technology experts Focus on few relevant experts when information not readily available	Potential component supplier Narrow search necessary to focus search efforts on relevant technology	Selected component supplier Focus on supplier necessary to obtain relevant components	Selected component supplier Obtain temporary assistance, if necessary
Search depth	Weak-Medium	Strong	Medium-Weak	Weak*
	Feasibility studies necessary to create relevant information Contract work but some specific information sharing necessary to enable feasibility studies	Conjoint prototype development Sharing expectations and requirements necessary to enable prototype development before access to real production specification is necessary	Information exchange regarding component specification necessary to coordinate component development Internal technology development to restrict external access to confidential information	Assistance with installation, if necessary Ambition to restrict external access to confidential information

If unanticipated issues occur the availability of information may be unclear, in which case more ad-hoc and in-depth interaction can become necessary. This is, however, the exception, and the companies try to avoid it by making substantial investments in preparation work and strong process development task forces
**Only in case of ZF and BMW*

When companies seek mainly conceptual capability contributions, breadth can be medium to broad. The results show that conceptual contributions help companies develop knowledge through information rather than application. Broad search incurs substantial costs, which can have a negative impact on innovation performance (Laursen & Salter, 2006). On the other hand, companies are likely to search broadly when they "do not have full information about which external source will provide the critical knowledge inputs to innovation. Given this uncertainty, managers are inclined to search broadly in order to be exposed to a large variety of potential knowledge inputs" (Terjesen & Patel, 2014, forthcoming). Conceptual capability contributions likely cost less than applied contributions because they do not require investments in joint collaboration. They therefore enable companies to focus available resources on covering a broad

range of potentially relevant external knowledge sources. Accordingly, the results document weak to medium levels of depth when companies seek conceptual capability contributions. This corroborates the ambition to invest resources in broad search, rather than drawing deeply on external knowledge, when relevant sources are yet to be identified. In fact, focusing on in-depth search early on could increase rigidity because companies may miss potentially relevant information (Terjesen & Patel, 2014).

The results document narrow search breadth but strong levels of depth for applied capability contributions. Applied capability contributions involve practical approaches to knowledge generation through conjoint activities with external partners. Close interaction and the mutual exchange of information become necessary to develop solutions in detail. Increasing depth is likely to have a positive impact on process innovation performance (Terjesen & Patel, 2014). Yet, close interaction also incurs higher cost, as companies invest substantially in relationships that allow them to draw deeply on external knowledge (Terjesen & Patel, 2014). The results suggest that companies seek applied capability contributions when they begin to focus on learning in more detail about one specific technology in more detail. This makes it obsolete to invest in broad search. Accordingly, the results show narrow search breadth when focusing on applied contributions.

Finally, the results suggest that capacity contributions involve narrow breadth and weak levels of search depth. Companies do need a service provider with the relevant capacity and capabilities to perform specific tasks. Yet, the results showed that in this context only non-critical tasks are performed by external partners. This does not involve close interaction, but instead clear, formal instructions.

The dynamic adjustment of openness, as discussed, above shows that the structure of interaction in technology transfer does not only have to fit with technology characteristics, as indicated by Stock and Tatikonda's (2004) model, but also with the changing motivation for interaction throughout the innovation lifecycle. The previous sections outlined general relationships between motivation for interaction and openness. Nevertheless, the results also document different patterns for enabling and core processes (Table 32). In this context, paths describe the timing of search breadth and depth adjustments during the innovation lifecycle. The evidence in the present study suggests that the different patterns result in part from differences in information accessibility but also from the managerial challenge of knowledge protection. The following sections discuss these determinants in more detail.

Proposition 3: *The motivation to work with external partners is a key determinant of the openness at each lifecycle stage, so that search breadth and depth are adjusted to enable different forms of external contributions at each stage.*

Proposition 4: *The different forms of external contributions companies seek throughout the innovation lifecycle reflect different configurations of search breadth and depth, regardless of the type of process a company develops.*

Proposition 4.1: *Conceptual capability contributions involve broader levels of search breadth and weaker levels of search depth than applied capability contributions, which require stronger investments in search depth but involve less search breadth.*

Proposition 4.2: *Companies are more likely to seek conceptual capability contributions before seeking applied capability contributions.*

Proposition 4.3: *Capacity contributions likely involve narrow breadth and weak depth of interaction in which only non-critical tasks are performed by external partners.*

7.1.4 The effect of information availability on openness

Information availability is defined as the extent to which relevant information is readily accessible from external sources without (additional) substantial up-front investments at any given stage. Companies can access readily available external knowledge easily and without significant investment. This enables companies to search broadly and identify relevant knowledge without investing in search depth. In this respect, the present study agrees with Terjesen and Patel (2014) that companies search broadly when it is not clear which source will provide the most appropriate solution, given that a variety of possible solutions exists. The present study, however, makes a further distinction between enabling and core processes, and therefore standard and core technology. The evidence suggests that companies are likely to find solutions for standard technologies more readily available than for core technology. Information on potentially relevant standard solutions is readily available and easy to access as multiple experts exist and actively seek to promote their knowledge and solutions (Gerwin, 1988). The companies reporting on standard solutions thus initially search very broadly to identify potential solutions and the differences between them. The companies only increase search depth once they commence detailed development and more specific information needs to be generated. This involves investment in a more in-depth, yet narrower search. To illustrate these issues, consider also the case of TEC.

The results revealed that TEC often cannot search broadly because information for the advancement of core technologies are not readily available. The task force in TEC described the issue that it seeks specific solutions that it identifies internally, yet these solutions are not typically available on the market. TEC therefore has to create information on these specific solutions, for example through feasibility studies and early prototype development, even before

an investment decision and detailed development take place. For this purpose a narrow range of external sources is relevant. Yet, the interaction with these sources is more in-depth than the reports by the others companies indicated. The same effect occurs in the other companies in this study when they need to create more specific information during the preparation stage. During installation, for example, only very specific information is necessary. This information is typically either available internally or readily available from external sources as all predictably relevant issues have been sorted out during the previous stages. Therefore, the installation stage in a typical project is characterized by narrow breadth and weak levels of depth.

Proposition 5: *Relevant external information is initially (during ideation and adoption) more readily available for standard solutions than for core technologies.*

7.1.5   The effect of knowledge protection on openness

The results show that the relevance of knowledge protection is a persistent theme at all stages of the innovation lifecycle. In this context relevance of knowledge protection is defined as the extent to which access to information that relates to critical or confidential knowledge becomes necessary in order to perform specific activities and create specific outputs. Moreover, the results show that the companies in this study structure their interaction with external partners in such a way as to restrict external access to internal knowledge when the relevance of knowledge protection is high. On the other hand, there are opportunities for the companies to work more openly with external partners at stages, where such knowledge is not yet relevant or specific enough to threaten the appropriation of process innovation. The results indicate that the relevance and managerial challenge of knowledge protection depend on the type of knowledge. In several cases the companies need to share knowledge on existing structures, interdependencies, or processes, which may be relatively unproblematic as it does not reveal any particularly confidential content. In contrast, all companies in this study were aware of the importance of protecting such contents that reveal confidential knowledge and are of potential value to competitors.[26] The relevance of critical insight for performing certain tasks and therefore the relevance of knowledge protection differs throughout the innovation lifecycle.

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[26] Structural knowledge and content knowledge can be distinguished (cf. Jonassen et al., 1993). The results show that in case of enabling processes, content knowledge typically refer to the data a new technology / software processes, rather than the technology itself. An example is SAP business enterprise software. The version and modules of SAP solutions a company uses is not confidential. The data that these technologies process, however, can be highly confidential. Such data can for example refer to product or production related specifications. In contrast the experiences by TEC related to technology development for core processes. In this case the critical content knowledge refers to the specification of new technology itself. This means for example that the components that are used, their measurements, their integration, and so on are confidential. The results for all companies show that the task forces consider structural knowledge as less confidential than content knowledge.

General relationship between knowledge protection and openness: Mapping openness against the relevance of knowledge protection reveals some general relationships between knowledge protection and openness as outlined in the following (see again Table 32). When the extent to which relevance of restricting external insight is low then interaction depth can be anything from weak to strong. When the extent to which the relevance of restricting external insight is high then the depth of interaction is preferably weak in order to restrict external access to confidential information. The results suggest that the more relevant knowledge protection becomes, the likelier it is that breadth is narrow. This claim is substantiated by the companies' aim to limit the number of external actors to which confidential information may leak. While Rönnberg-Sjödin (2013) argues that a common understanding between partnering companies can provide sufficient safeguards for knowledge protection, the results in the present study clearly suggest that companies seek secrecy when confidential information is concerned and structure the openness to external contributions accordingly. The following section elaborate on this issue in more detail.

Differences between enabling and core processes: The results suggest that the relevance of knowledge protection affects the adjustment of openness, and therefore the forms of external contributions companies seek throughout the innovation lifecycle. The timing when restricting external access becomes relevant differed between the cases reporting on the development of enabling and core process. The patterns of obtaining different forms of external contributions throughout the innovation lifecycle therefore differ for enabling and core processes.

All companies seek conceptual capability contributions early on. The study shows that companies share their expectations and requirements at a general level. They do not, however, convey critical, detailed information at this stage. In fact, companies may even find it difficult to specify expectations and solutions (Rönnberg-Sjödin, 2013). Yet, the results show that BMW, KNORR, TKMS, and ZF seek further conceptual capability contributions during adoption. Only during preparation they obtain primarily applied capability contributions.

The close interaction necessary for applied capability contributions makes it difficult to restrict insight for external partners (cf. Wagner & Hoegl, 2006). The results of the present study, however, show that close interaction with external partners for the development of enabling processes does not require the sharing of confidential information. For enabling processes and external standard solutions, the technology itself is likely to be less confidential than the data it processes. The results suggest that it is relatively easy to restrict external access to confidential information and still obtain useful support. According to the task forces' reports, it is, for example, not necessary to share product descriptions or the settings of production equipment that new software is supposed to process, in order to obtain external support for the

modification of such technology. Instead, it suffices to clearly specify what is expected of the technology (e.g. process a certain amount of data in a certain format). Furthermore "dummy data" can be used for testing purposes if necessary. The present study therefore agrees that for non-core technologies or non-core capabilities, i.e. such technology and capabilities that relate to the company's enabling processes but are not directly involved in the company's core processes, there is no need for strong control (Chiesa & Manzini, 1998; Lager & Frishammar, 2012). Moreover it shows that knowledge protection is not necessarily a significant managerial challenge in this case, even though there is in-depth interaction with external partners to learn about new technology and modify it prior to installation.

TEC, in contrast, seeks applied capability contributions earlier on than the cases discussed above, namely at the adoption stage. Early applied capability contributions are necessary to enable TEC work more independently during preparation. Accordingly, TEC obtains restricted applied capability contributions during preparation. In contrast, to the other cases this is important for TEC in order not to reveal critical knowledge during preparation (cf. Lager & Frishammar, 2012). For core processes, confidential knowledge is likely to be directly embedded in the new technology and the surrounding production system. Core technologies are often developed in a real operating environment (Lager, 2011). As a result, there are fewer opportunities to withhold confidential knowledge from external partners if they have to be involved for development work. This makes it all the more important to restrict external insight during preparation, or to apply specific protection strategies when partner involvement is unavoidable. Earlier research has suggested that the development of new technology mainly takes place at the supplier site (Rönnberg-Sjödin & Eriksson, 2010) and that companies should engage in close collaboration with external partners for the development of new processing equipment (Lager & Frishammar, 2012). The present study suggests that companies seek external development and close collaboration only in the case of standard solutions for the development of enabling processes. On the other hand, Chiesa and Manzini (1998) recommend strong integration when collaboration relates to technological competencies that directly affect core operations. In their article this refers to mergers and acquisitions, which is clearly not possible for every individual innovation project. The present study reveals that companies are inclined to develop core technology internally and only acquire components from external sources. Rather than seeking close integration for individual projects, companies may often prefer exclusive operational arrangements with component supplier in order to prevent knowledge leakage.

During installation companies transfer new processes into operation and seek to restrict external access to internal operations. The results for enabling and core processes converge at this stage. BMW, KNORR, TKMS, and ZF reported that when the new technology is configured

and actual data are inevitably imported into the new system, it becomes important to restrict access for external partners and to configure the technology internally. Likewise, TEC performs installation and configuration mainly internally. This shows that companies seek to restrict external insight and require mainly capacitive support, for tasks that can be clearly defined, monitored, and evaluated. These can be clearly defined, monitored, and evaluated. All tasks of competitive relevance remain internal. The findings thus suggest that from the point when access to confidential knowledge becomes necessary, companies aim to restrict their interaction with external partners. The critical point at which such knowledge becomes necessary, however, differs for the development of enabling and core processes.

In conclusion these patterns show that as companies adjust openness throughout the innovation lifecycle they adjust their approach to knowledge sharing and protection. The innovation management literature frequently argues that due to the weaknesses of institutional mechanisms, secrecy is the most effective means to appropriate process innovation (James et al., 2013; Milesi et al., 2013; Teece, 1986). Yet, the results in the present study show that the interaction with external partners at the stages preceding the operation of new processes, makes it necessary for companies to manage the tension between knowledge sharing and protection more dynamically than by strictly maintaining secrecy. This finding concurs with recent assertions that the effectiveness of knowledge protection for successful innovation is determined by the strategic application of knowledge protection rather than the strength of specific protection mechanisms (Hurmelinna-Laukkanen, 2011).

In particular, the findings suggest that the relevance of restricting external access to critical internal knowledge at a given lifecycle stage affects the adjustment of search breadth and depth at that stage and differs depending on the type of process a company develops. Project scope did not yield evidence for different adjustments of openness. The evidence also gives good reason to suggest that the availability of relevant external information at a given lifecycle stage affects the adjustment of search breadth and depth at that stage and differs depending on the type of process a company develops. Based on the discussion above and drawing on Table 31 the following propositions are put forward:

Proposition 6: *Information availability and relevance of knowledge protection affect openness.*

Proposition 6.1: *With higher relevance of knowledge protection companies are likely to decrease their search breadth and depth regardless of information availability. However, for lower levels of knowledge protection relevance search depth is stronger when information availability is limited.*

7.1.6 Key findings on external contributions to technological change

The previous sections discussed lead to the emergence of a construct for external contributions to technological change in open process innovation. Figure 20 provides a visual summary of the findings. The construct can be summarized as follows.
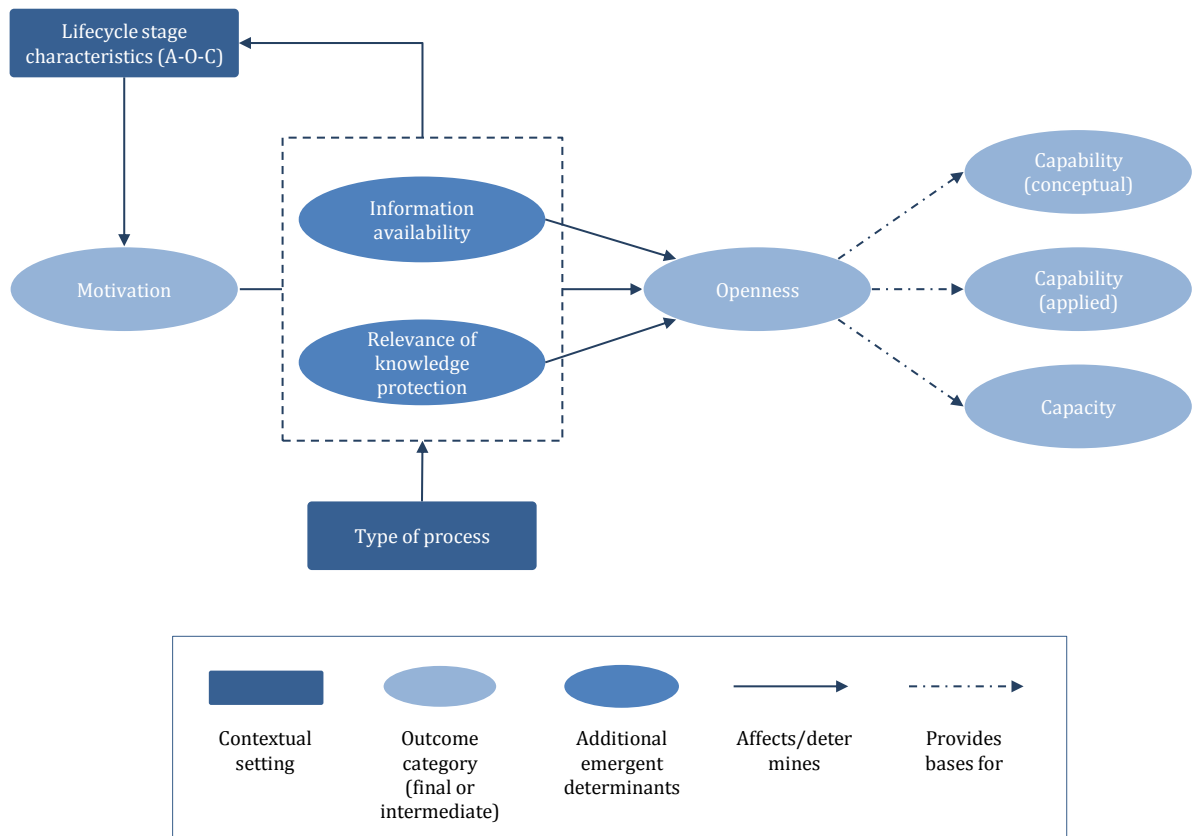
Figure 20: External contributions to technological change

Different external contributions to technological change: The study shows that the motivation to work with external technology partners changes throughout the innovation lifecycle, depending on the lifecycle stage characteristics. Moreover, the findings suggest that companies adjust openness to fit with the motivation. Against this background the study shows that companies seek different contributions to technological change throughout the innovation lifecycle. These can be constructed as capability and capacity contributions. Moreover, capability contributions can be conceptual or applied. The findings reveal different configurations of openness (search breadth and depth) underlying the different forms of external contributions to technological change. When companies aim to learn and develop new capabilities they will seek capability contributions. Conceptual capability contributions involve broad search but weak levels of depth. Applied capability contributions are typically sought from a very narrow range of partners but involve medium to strong levels of depth, typically in form of close interaction, investment, and time (Wagner & Hoegl, 2006). Companies are, therefore, more likely to seek

conceptual capability contributions before making investment decisions. When companies possess sufficient internal capabilities they will tend to only seek external capacity contributions. Capacity contributions, involve narrow search breadth and weak levels of depth.

Information availability and knowledge protection: In spite of the general relationships between motivation for interaction and openness involved in different forms of external contributions, the results reveal different patterns with regard to the lifecycle stages at which the companies in this study seek specific contributions depending on the type of process they reported on. The results suggest that information availability and the relevance of knowledge protection at any given stage affect openness, and therefore the form of external contribution companies seek. If information is readily available, companies do not need to engage in in-depth interaction with external partners to obtain knowledge. Instead, they may invest in broad search to gain an overview of the most suitable solutions. In contrast investment in more in-depth, yet narrower search is necessary when new information in not readily available and needs to be created. As the results suggest that the availability of external information differs for core and enabling processes, the results describe different patterns of openness for the development of core and enabling processes respectively. Furthermore, the results of the present study suggest that on the operational level companies manage knowledge protection in open process innovation more dynamically than by strictly maintaining secrecy. The protection of internal knowledge gains increasing importance during preparation and installation, when process specification becomes more definite as it is less feasible to withhold confidential content from external partners. The results further suggest that with increasing relevance of knowledge protection, companies aim to restrict external insight by searching more narrowly and with weaker levels of depth. For enabling processes this may become important later on than for core processes. Information availability and relevance of knowledge protection directly affect the openness of a company to external technology contributions. The anticipation of information availability and knowledge protection may even affect the lifecycle stage characteristics at each stage. As information availability and relevance of knowledge protection seem to depend on whether a company develops core or enabling processes, the type of process a company seeks to develop and implement emerges as a major distinguishing factor for the management of open process innovation.

7.2 Methodological guidance by management consultants

The results document the motivation for obtaining external support for process development and implementation in the form of methodological guidance. This contribution relates neither to technological nor organizational change directly. Instead, methodological guidance refers to a

range of contributions that help task forces identify and evaluate potential solutions and manage innovation projects. The results suggest that methodological guidance is the domain of external consultants. The most prominent type of consultant in the reports for this study are management consultants with distinct expertise in managing technological process innovation, although they do not perform technological change themselves.[27] The results suggest that management consultants are important at the early stages of the innovation lifecycle and are mainly involved in projects with a broad scope. The following sections discuss these insights in further detail.

7.2.1 Contributions by management consultants

The results of this study suggest that management consultants can provide methods and tools to task forces which help establish the foundation for process development and implementation. More specifically, such tools include methods for documenting existing structures and processes during ideation, as well as methods for gathering feedback and evaluating external solutions during adoption decision making.[28] As methodological contributions provide a framework for further development work they are necessary early on. Accordingly, the results show that the companies mainly work with management consultants at the early stages of the innovation lifecycle (ideation and adoption). During preparation and installation external consultants may occasionally provide capacity for project management but the results do not provide evidence for significant contribution to developing or further shaping the new process during these stages. By contributing to ideation and adoption, management consultants play a key role at important direction-setting points in the innovation lifecycle. This indicates that management consultants are more important contributors to a company's process innovation efforts than the existing literature on open process innovation suggests (cf. Frishammar et al., 2012; Linton, 2000).

The contributions by management consultants to product and process development are often associated with the promotion, diffusion, and implementation of new technologies and organizational practices across industrial boundaries (Reichstein & Salter, 2006; Wright et al., 2012). However, Reichstein and Salter (2006) found that management consultants were unlikely to induce technological process innovation among manufacturing companies across various industries. More specifically, they found that the interaction with consultants made it less likely

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[27] Of course there are technology companies that also offer consulting services. They do, however, often send different teams for consulting services and technological change services.

[28] For example, it was necessary to understand the existing processes and inter-dependencies in order to scope the process innovation project. This required methods to document and appraise the existing processes. Management consultants provide the companies with these methods and thus help to establish the basic foundation for further decisions and development work. Moreover, the decision making methods that consultants provided enable a structured and transparent decision making process.

for companies to develop and implement new processes. They remain unclear as to the type of consultant they refer to, but suspect that the main contributions by external consultants are "diffusion of new practices across industries and [providing] critical inputs to help firms develop new products or processes" (Reichstein & Salter, 2006, p. 659).

Reichstein and Salter (2006) suspect unobserved company characteristics as the main reason why they find no evidence for a positive effect of management consultants on process innovation adoption. The evidence in the present study, however, suggests that the importance of management consultants for technological process innovation lies with the provision of relevant methodological tools during the front-end innovation lifecycle rather than the brokerage of technological content to induce technological process innovation. From an open innovation perspective, these contributions are particularly interesting, given that they constitute a case of leveraging external developments (i.e. methods) to advance internal development projects, although the external knowledge does not directly relate to the new development itself but rather to facilitating its development through the use of new external knowledge.

The present study concurs with Reichstein and Salter that management consultants are not a source of innovative technologies or organizational practices that induce process innovation. Furthermore, this thesis does not provide evidence to support the notion that consultants increase the proclivity for organizational change in technological process innovation (cf. Hislop, 2002; Swan et al., 1999). Instead, the insights in the present study provide empirical evidence that external consultants make primarily methodological contributions (cf. Bessant & Rush, 1995). Such methodological contributions do not directly relate to technological or organizational change. They do, however, inform a company's process innovation efforts with regard to the foundation and structure of such projects. Methodological contributions by management consultants are therefore particularly relevant at the early stages of the innovation lifecycle.

Proposition 7: *Management consultants are more likely to be involved and provide methodological guidance at early stages of the innovation lifecycle than at later stages of the innovation lifecycle.*

7.2.2   The effect of project scope on the involvement of management consultants

While the study reveals insights into the contributions of management consultants, the results also point towards the effect of project scope on the motivation to work with management consultants. Earlier literature finds that companies typically seek the support of technology consultants in complex technology acquisitions (Dawes et al., 1997). Similarly, the present study shows that management consultants mainly contribute to projects with a broad scope, which the

companies consider as particularly complex. Every report on the involvement of management consultants was on the development of enabling processes (see BMW and ZF). Yet, not every report on the development of an enabling process also involved management consultants (see KNORR and TKMS). The cases differ in the scope of the projects that they reported on. The replication logic underlying the present study thus indicates that management consultants are mainly important for projects with a broad scope (as reported by BMW and ZF). Broad scope projects are organizationally complex as they involve technological and organizational change and affect multiple departments and stakeholder groups at the same time. In such projects the task forces found that methods and capabilities for project scoping and solutions evaluation were particularly important. Consultants can provide task forces with powerful tools to prepare decisions systematically and transparently in the context of such complex organizational inter-dependencies, costly investment, and potentially divergent stakeholder perspectives. Conversely, the results show that companies are less likely to work with management consultants on technology development projects with a narrow scope that only involve minor organizational changes in a single department. In such settings internal expertise and capacity are more likely to suffice and do not necessarily justify the costs of involving external consultants (Bessant & Rush, 1995).

Proposition 8: *Management consultants are more likely to be involved and provide methodological guidance in broad scope projects than in narrow scope projects.*

The case of TEC provides further illustrative insight into the role of consultants in process innovation and also points towards avenues for further research. The experiences reported by the TEC task force relate to projects with a narrow scope on the development of new production technology for core processes and only involve limited organizational change. The task force in TEC explicitly stated not to work with management consultants. The task force clearly considered itself to possess an in-depth understanding of the critical technologies as well as the organization of the production facility. As these are core operations of the company, they were likely to be unique to TEC. Therefore, the company considered it very unlikely that external consultants would possess relevant experiences from similar projects in other companies. Furthermore, the results show that TEC is generally reluctant to share information relating to its core processes. This, however, would be necessary to enable a consultant to make a significant contribution that is tailored to the company. The reports from TEC therefore suggest that due to the knowledge advantage and appropriation of innovative technologies, there is only very limited potential to involve management consultants in projects with a narrow scope on technology development for core processes. However, the study does not allow for any conclusions regarding the involvement of management consultants in core process development projects with a broad scope as there were no data on such a case available for the present study.

Such projects may be particularly complex. This makes it very likely that companies engage with management consultants to develop a structural framework for the management of such projects. Further research is necessary to investigate this contingency.

7.2.3 Key findings on contributions by management consultants

The previous sections discussed the contributions by different types of external partners and particularly highlighted the relevance of external management consultants as sources of methodological guidance. The findings suggest specific conditions for the involvement of management consultants in open process innovation. The key insights from this discussion can be summarized as follows.

Methodological guidance: The findings of the present study contribute to theory by providing empirical evidence for the contributions of external management consultants to process innovation from a lifecycle perspective and identifying contingencies for their involvement. The results concur with the insight from earlier conceptual literature and primarily emphasize the support of management consultants for process appraisal and evaluation (Bessant & Rush, 1995). More specifically, the findings suggest that management consultants help to shape process innovation by providing methods to enable companies to establish the foundations for new process development, rather than by diffusing technological change or organizational practices directly relating to new processes.

Determinants of management consultants' involvement: The results suggest that such methodological contributions actively shape process development at the early stages of the innovation lifecycle. Moreover, the results suggest that external methodological guidance is particularly necessary in projects with a broad scope. Narrow scope enabling processes may neither require nor justify the involvement of costly consultants. For narrow scope process innovation in core operations consultants may not possess the relevant capabilities to make relevant contributions.

7.3 The nature of further external contributions

The results show that the task forces across all companies that participated in this study are keen to develop and communicate organizational change without external support. Earlier literature suggests that external change agents are critical contributors to organizational changes or management innovation (Birkinshaw et al., 2008). The findings, however, show that among the companies in this study there were no significant external contributions towards organizational change as a response to the introduction of new technology. General resistance

against organizational change, limited acceptance of external partners among the operating base, and limited organizational insight were the main reasons for the lack of motivation to obtain external contributions to organizational change. Nevertheless, the results indicate that companies do obtain relevant information on organizational change and even systemic impact management through the interaction with their external partners, albeit indirectly. The following sections discuss why external contributions to organizational change are limited and develop the construct of indirect external contributions in more detail.

7.3.1   Limited direct contributions

The preference for technological change and maintaining the organizational status quo, if possible, is a common thread in the reports by all companies in this study. The task forces are aware that some extent of organizational change is necessary for most process innovation and especially for the introduction of standard solutions. The greater the level of customization to standard solutions, the greater the risks and problems associated with being able to maintain and upgrade such systems in the long term (Brehm et al., 2001; Hislop, 2002). Therefore, companies have to consider adapting their existing organization, especially when seeking to leverage the benefits of standard solutions. The reports from all companies and lifecycle stages suggest that the task forces consider planning and evaluating organizational change more difficult than technological change. The task forces are particularly wary of organizational change because they anticipate general opposition among the operators. Resistance against organizational change may impede process innovation success, as bottom-up acceptance is critical for process implementation (Meyers et al., 1999). The results further show that the task forces consider communication with operators as the main practice to address resistance against organizational change. Resistance against organizational change often results from social uncertainty (Gerwin, 1988). Communication is thus particularly important towards the end of the innovation lifecycle, when change becomes apparent to the broader operating base. At the same time communication is a delicate issue because organizational change may affect the operators' personal employment status. Against this background the companies suggested that external change agents were not well enough accepted among the operating base to conciliate opposition against change (see BMW and ZF). In fact, the task forces suggested that greater acceptance could be expected when internal members communicated organizational change (see for example the case of KNORR in section 5.2).

Proposition 9: *In technological open process innovation projects it is less likely that companies will seek direct contributions from external partners to organizational change than to technological change.*

"Not-one-of-us syndrome": The findings in the present study differ from earlier literature, which stresses the importance of external change agents to drive organizational change by legitimizing changes and supporting credibility (Birkinshaw et al., 2008). The earlier studies, however, concentrated mainly on external support for managerial innovation at the organizational level. At this level managers may be willing to accept external support for organizational change to access external expertise that is more advanced than the expertise available within the company (cf. Menon & Pfeffer, 2003). However, this does not seem to apply to the technological process innovation at the center of the present study. For the purposes of this study, the task forces reported on process innovation projects in which organizational change occurs as a response to technological change. These organizational changes directly relate to the operators' work experiences, into which external actors generally have only limited insight. Against this background the task forces' experiences suggest that operators are reluctant to support or accept change from external change agents because they assume that the external actors do not sufficiently understand or appreciate the work they do. In this respect the findings resemble the existing technology transfer literature, which often documents a resistance to various forms of external input under the umbrella term of the "not-invented-here" syndrome (Katz & Allen, 1982; Lager & Frishammar, 2010). The results of the present study, however, show that according to the task forces' experiences, external technology support is generally more readily accepted than external support for organizational change. This insight points towards a "not-working-here" or "not-one-of-us" variety of the well documented "not-invented-here" syndrome. Previous literature argues that learning new things and unlearning old things creates anxiety and resistance (Piderit, 2000; Walsh & Ungson, 1991). The present thesis shows that such effects may be particularly significant when change is introduced from outside. Earlier literature suggests that consultants may be useful to implement unpopular change (Bessant & Rush, 1995). If unpopular change refers to issues such as letting employees go external change advocates may be useful. In this case the operators affected by the change will likely have little impact on process implementation success. However, this thesis suggests that it may be problematic to involve external partners for the introduction of new processes, if subsequently operators have to work with it. Process innovation, however, requires operators to embrace change, in order to execute new processes properly (Meyers et al., 1999). The results of the present study indicate a general reluctance among operators to readily accept change from external partners. Operator acceptance is important and therefore they have to be convinced of change rather to have it enforced upon them. Against this background the present study clearly finds that internal change agents are necessary for the communication of organizational change and to address internal resistance against change. Therefore, this thesis argues that it if operators have to work with new processes it may be problematic to involve external partners for the introduction of such changes.

Proposition 10: *Limited internal acceptance of external partners among the operating base impedes direct external contributions to organizational change.*

Lacking organizational insight: All the companies who participated in this study expected that organizational change and systemic impact management always requires an in-depth understanding of the company-specific context to which change applies (e.g. structures, processes, culture, history, etc.). At the same time, the task forces suggested that external actors did typically not have sufficient organizational insight to drive organizational change. Because organizational knowledge is often tacit and experience-based it is difficult to convey to external actors (Amit & Shoemaker, 1993; Birkinshaw et al., 2008). In this context, the task forces across all companies in the study suggested that external partners could only contribute to organizational change by pointing towards typical areas of organizational change or emphasizing the need to consider organizational change. While external actors may have acquired experiences relating to organizational change in processes that are similar across client companies, the details of these processes and the culture of dealing with change are likely to be different in every company. Of course there can be strong ties with external partners who have a sophisticated understanding of the company. Nevertheless, for various contingencies (e.g. new top-management, new technologies, legislation, best offer, etc.) may prompt companies to work with experts with whom they have no prior relationship. It is a risk that external recommendations for organizational change may not fit the company-specific context (Bessant & Rush, 1995). Similarly, earlier literature suggests that the lack of organizational insight impedes external contributions to systemic impact assessment (Gopalakrishnan & Bierly, 2001). The lack of organizational insight was Huizingh's (2011) main concern about the applicability of the open innovation paradigm to the domain of process innovation. In this respect the present study shows that organizational change and systemic impact management are indeed predominantly internal responsibilities. In fact, the results throughout all lifecycle stages show that the task forces interact with various internal stakeholders to acquire information that allows them to understand the consequences of technological and organizational change for people, systems, procedures, and organization (cf. Gerwin, 1988; Tyre & Hauptman, 1992). Nevertheless, the results also show that task forces were motivated to obtain knowledge from external technology experts and management consultants that would enable them to draw conclusions on organizational change and systemic impact management.

Proposition 11: *Limited organizational insight of external partners impedes direct external contributions to organizational change.*

7.3.2 Indirect contributions

The results across all stages show that in contrast to technological change, the nature of contributions to other process innovation components is implicit or indirect. The task forces across all cases repeatedly suggested that they translated external information on specific technology or methodology related matters into relevant knowledge on organizational change and systemic impact management. The information that external partners provide on the limitations of technological adaptability, for example, also informs decisions on necessary organizational changes. Similarly, methods provided by external management consultants help task forces plan organizational change and systemic integration. However, the external contributions do not relate to these activities directly but merely enable them.

The findings also complement previous literature on external contributions relating to the systemic impact of process innovation (Chesbrough & Teece, 2002; Gopalakrishnan & Bierly, 2001). Gopalakrishnan and Bierly (2001), for example, find that systemic innovation incurs significant coordination efforts and requires substantial information exchange which may threaten knowledge protection. They suggest that companies are therefore more likely to source systemic innovations internally, i.e. that external contributions to the systemic aspects of process innovation are limited. This thesis corroborates this assertion to the extent that the companies in the present study do not directly source external contributions to the management of systemic impact. Yet, the external knowledge the companies source enables them to assess systemic impact and manage systemic integration with increasing precision as the lifecycle advances. Robertson et al., (2012), suggest that the systemic integration of new processes may be coordinated by the company but is actually performed by external partners. The present study shows that although the change that is necessary for systemic integration may be performed to some extent by external partners (e.g. technology modification, installation), the planning and conceptualization of systemic integration is a result of the task forces knowledge assimilation and transformation efforts.

The insights on indirect contributions as advanced in the present study differ from other references to indirect contributions in the literature. Previous literature mainly emphasizes the indirect access to new knowledge. This includes, for example, gaining access to knowledge through indirect channels such as network ties (Salman & Saives, 2005), patents and surveys (OECD, 2009; Perkmann et al., 2011) or reverse engineering (Cassiman & Veugelers, 2000). These contributions describe indirect access to specific information. They suggest that companies seek specific information that directly relates to a specific issue through indirect channels to the knowledge source. The findings of the present study, however, suggest that information relating to one specific issue also informs a company on other issues that the

information itself does not directly relate to. In a similar vein, Grimaldi and von Tunzelmann (2002) suggest that there can be future outcomes resulting from general research collaborations that are not anticipated at the time of collaboration. The findings of the present study, however, point towards the exploitation of knowledge within the same project. Furthermore, such indirect contributions also differ from knowledge spillovers. Practitioners and scholars alike, usually consider spillovers as the result of unintended knowledge leakage and appropriability problems (Gnyawali & Park, 2011; Ornaghi, 2006). The indirect contributions identified in the present study, however, result from a company's internal knowledge transformation processes (cf. Lane et al., 2006) rather than access to external actors' ill-protected knowledge repositories. The role of knowledge transformation emphasizes the task force's intermediation role, and the deployment of necessary absorptive capabilities. This is discussed in section 7.4 of this chapter. Against this background the present thesis describes indirect contributions in the following way: indirect contributions refer to information that is provided by an external source with the intent to directly enable the recipient to solve a particular issue, yet knowledge assimilation and transformation lets that recipient perform a further task or solve another issue to which the received information did not originally relate to. It is a necessary condition of such indirect contributions that the indirectly supported issue relates to the same project as the issue which the information originally addressed. Furthermore, the information has to be provided voluntarily and not accessed through unintended knowledge spillovers in order to qualify as a contribution. As far as the structure of interaction for indirect contributions is concerned, the evidence in the present study does not provide any specific insights on the effects of breadth and depth on indirect contributions. This remains for further research to explore. Figure 21 describes the mechanisms of indirect contributions, as outlined in the previous.

Proposition 12: *In technological open process innovation projects companies are likely to obtain external support for organizational change, systemic impact management, and mutual adaptation predominantly through mechanisms of indirect contributions.*
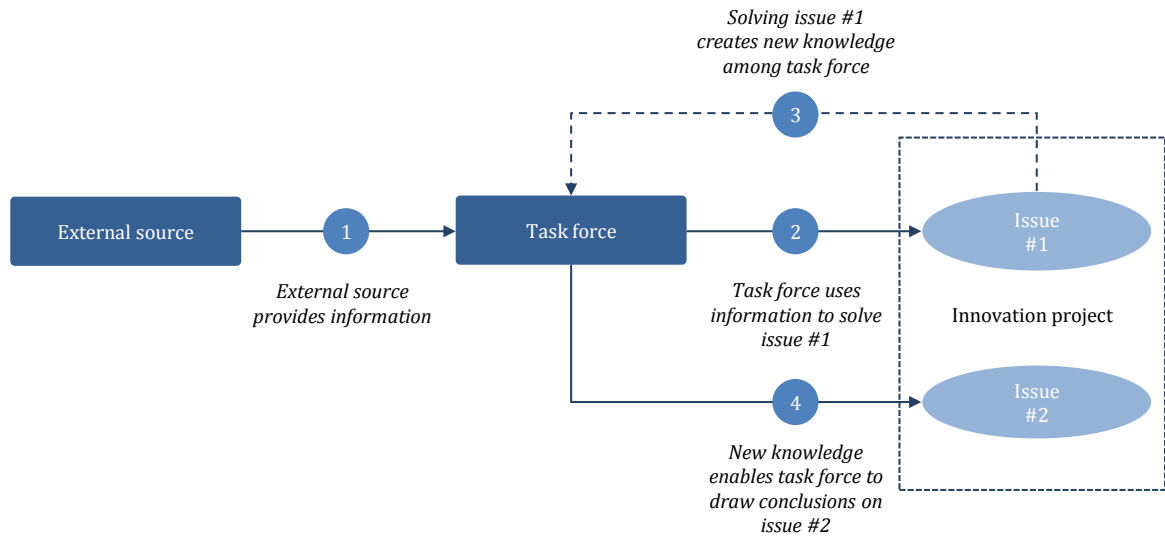
Figure 21: Indirect external contributions

7.3.3 Key findings on limited and indirect external contributions

The previous sections discussed the reasons for limited external contributions to process innovation components other than technological change and identified a construct of indirect external contributions to technological change in open process innovation. The construct can be summarized as follows.

Limited external contributions: The findings of the present study point out the factors impeding external contributions to process innovation components other than technological change (mainly organizational change and systemic impact). In particular, the findings suggest that external actors may not be sufficiently accepted among internal stakeholders to address resistance to organizational change. Moreover, a lack of organizational insight impedes the ability of external actors to make specific contributions to organizational change and systemic impact that are appropriate to the client company's context.

Indirect external contributions: The present thesis suggests that companies mainly seek indirect external contributions to organizational change and systemic impact management, and the management of mutual adaptation. The findings do not categorically rule out direct external contributions to these process innovation components. They do, however, suggest that these components are predominantly the domain of the internal task force and external support is likely to be indirect. This emphasizes the importance of a well-trained gatekeeper task force that is able to translate external knowledge for application within the company.

7.4 Capability deployment for open process innovation

The present study describes process innovation as the deliberate, mutual adaptation of new technology and existing organization. Deliberate process development presupposes access to new technology and organizational insight. In open process innovation, companies leverage external knowledge and technology to advance internal processes. This presupposes that companies possess capabilities for absorbing external knowledge and integrating new processes with the existing organizational system (Robertson et al., 2012). The results and the discussion at the individual stages show how companies absorb external knowledge and technology and draw conclusions on the need for further changes. Against this background this thesis also investigated the deployment of capabilities for managing the knowledge and technology transfer across organizational boundaries. According to Lewin et al. (2011) such "external absorptive capacities" (p.86) include all routines and practices for external knowledge identification, learning from external partners, and transferring knowledge back into the company. These practices are critical to facilitate the interface between companies and the external environment. With reference to earlier literature, relevant capabilities enable companies to recognize, explore, assimilate, transform, and exploit new knowledge (Cohen & Levinthal, 1990; Lane et al., 2006; Robertson et al., 2012; Todorova & Durisin, 2007; Zahra & George, 2002). Additionally, the findings pointed towards a capability for enabling external partners to make contributions. The following sections discuss these insights in further depth.

7.4.1 Capability deployment at different stages of the innovation lifecycle

The results and analysis of the individual lifecycle stages suggest that companies absorb external knowledge gradually. The companies in the present study deploy several capabilities simultaneously and across multiple stages. Yet, the results also show that the routines and practices underlying these capabilities change. In this context the results reveal a specific pattern of knowledge absorption. The table below shows the deployment of capabilities in terms of the changing meta-routines that reflect them (Table 33).

Table 33: Capability deployment across the innovation lifecycle

AC	Innovation lifecycle			
	Ideation	**Adoption**	**Preparation**	**Installation**
Recognition	Understand potential value of external knowledge sufficiently well to describe process candidates			
Explorat.	Understand potentially relevant external knowledge sufficiently well to describe process candidates	Probe potential benefits of process candidates		
Assimilat.	Translate external information to company context for pre-selection	Understand external information in more detail and sufficiently well to clearly describe solutions and establish project plans	Understand new information in more detail to integrate it with existing knowledge	Minor knowledge assimilation through still increasing understanding of new knowledge
Transform.	Early estimation of potential changes to existing knowledge base for pre-selection	Initial internal knowledge diffusion to refine expectations and requirements based on increasing understanding of new information	Integrate new information with existing knowledge to generate transformed knowledge base	Diffuse new knowledge internally to alter broader knowledge base
Adaptation			Apply new information to change the technology to make it fit with the organization and integrate it with the organizational system	Installation and training to implement new technology and potentially discover further issues
Integration			Apply new information plan and coordinate organizational change to enable integration of new knowledge and technology	Actual introduction of technological and organizational change to implement process and diffuse new knowledge
Exploitation				Initial operation of technological and organizational change to start commercial application of new knowledge
Enabling	Enable external actors to create relevant information when not readily available	Convey information to external partners to enable provision of relevant information	Provide external partner with information to make contributions and protect critical knowledge	Specify tasks for external partners and restrict external to internal knowledge base access if necessary

Text in the middle describes meta-routines

The findings suggest the following process of knowledge absorption. Initially the gatekeeping task force recognizes and explores valuable external knowledge. This is coupled with initial assimilation and transformation processes among a limited group of internal stakeholders. The new information enables concept development and decision making. This also involves further assimilation and transformation, as the task forces develops a better understanding of the new information and disseminates it to decision makers and key operators. Practical capabilities for adaptation and integration become necessary for the detailed development of technological and organizational change during preparation. However, the detailed development and increasing involvement of operators also lead to further assimilation of new information and transformation of the existing knowledge base. In contrast to earlier lifecycle stages assimilation and transformation are influenced by practical rather than conceptual absorptive capabilities. Likewise, the installation and exploitation of new processes requires practical abilities to implement technology and disseminate new knowledge internally and triggers further transformation and potentially further assimilation. Throughout the entire knowledge absorption process, the task force acts as a gatekeeper or process champion and transfers new knowledge and technology into the company and to different parts within the company (cf. Cohen & Levinthal, 1990; Lewin et al., 2011). The patterns of meta-routines are similar for core and enabling processes. Nevertheless, the underlying practices and routines of deploying specific capabilities may differ between the cases of developing enabling and core processes.

The present study suggests that transformation and assimilation occurs throughout the entire lifecycle, even during the initial search. The findings of the present thesis clearly show that recognition and assimilation occur before the decision to acquire new knowledge or technology. Patterson and Ambrosini (2015) present similar findings when they discuss "assimilation before acquisition". However, the present study further shows that not only assimilation of external knowledge but also transformation of internal knowledge commences once the task force begins searching for new knowledge and recognizes its potential value. Assimilation and transformation do not occur in isolation. The different capabilities that a company deploys are not independent but interactive (cf. Patterson & Ambrosini, 2015; Todorova & Durisin, 2007). The study agrees with Todorova and Durision (2007) and Patterson and Ambrosini (2015) that transformation and assimilation interact with other AC capabilities. This is reflected in the finding that absorption shifts from the conceptual to the practical level as the lifecycle advances. During the early stages assimilation and transformation occur together with recognition and exploration. During the later stages they occur conjointly with adaptation, further exploration, and exploitation, which denote the practical application of new knowledge (cf. Robertson et al., 2012). The results illustrate the differences between the conceptual and applied stages of knowledge absorption by the different routines that companies enact to deploy absorptive

capabilities. This indicates that the gatekeeping task force requires the abilities not only to work at an abstract level but also to engage with more practical changes in order to manage knowledge absorption throughout the innovation lifecycle. This perspective reveals a dynamic perspective on capabilities, in which companies deploy capabilities as to enable different external contributions, manage knowledge protection, and adjust search breadth and depth throughout the innovation lifecycle. The set of relevant capabilities and their dynamic, practice-based deployment makes up the foundation for a company's capacity to manage open process innovation (cf. Lewin et al., 2011).

Proposition 13: *Knowledge absorption occurs as a gradual process as companies deploy multiple capabilities simulatenously and across multiple stages, yet the underlying meta-routines by company deploy the capabilities change.*

Proposition 13.1: *Knowledge assimilation and transformation processes occur throughout the entire innovation lifecycle but their focus shifts from conceptual practices in conjunction with recognition and initial exploration at the early lifecycle stages to more practical knowledge absorption processes in conjunction with further exploration, adaptation, integration, and initial exploitation at the back-end innovation lifecycle.*

7.4.2   Capability to enable external partners

The findings across all lifecycle stages point towards the central importance of conveying internal knowledge to external partners. Sharing internal knowledge is necessary to enable external partners to make a relevant contribution. To receive knowledge from external sources the task force needs the ability to convey what information it seeks (cf. Robertson et al., 2012). This is a challenge if internal knowledge (e.g. processes and structures) is poorly documented and largely tacit in nature. Such knowledge is difficult to share within the limited amount of time available during the process innovation lifecycle (Amit & Shoemaker, 1993; Nonaka, 1994). At the same time, task forces have to structure their interaction with external partners in a way so that confidential knowledge is protected. This presupposes the ability to evaluate the criticality of internal knowledge and re-emphasizes the relevance of knowledge assimilation and transformation. Companies need the ability to understand external knowledge and its applicability in the company-specific context; even when external partners do not have (and are not supposed to have) full information about this context. The capability to enable external partners thus builds on a set of practices by which companies provide sufficient information yet structure interaction in such a way as to protect confidential internal knowledge. Examples from the case studies include ZF's distribution of catalogues of expectations and requirements to facilitate standardized knowledge sharing and solution presentations, TKMS showing external

partners its dockyard to convey the complexity of its products, or BMW's need-to-know guidelines (see the case of BMW in section 5.1).

Enabling external partners during interaction: This thesis presents enabling capability as an operational level construct. At this level, companies need to enable external contributions during temporary appointments, rather than plan for long-term, strategic partnerships. Earlier studies have discussed similar alliance management capabilities at the aggregate company-level. Schreiner et al. (2009), for example, show that conveying "information that enables a partner to understand its market position, competencies, organizational features, and value proposition" (p. 1407) is a necessary capability for engaging in successful inter-organizational alliances. Yet, Schreiner et al., (2009) investigate alliances as strategic-level phenomena. They study the effect of alliance capabilities on aggregate company-level measures, such as "what percentage of their marketing/promotional events per year are conducted together with their partner?" (p.1407). The present study, in contrast, identifies capabilities at the operational, project-stage level. This perspective reveals that companies can adjust openness throughout the innovation lifecycle to account for motivation and knowledge protection at a given lifecycle stage. Accordingly enabling capabilities are deployed dynamically at the different stages of the innovation lifecycle. Such enabling capabilities are similar to desorptive capacities (Lichtenthaler & Lichtenthaler, 2009; Müller-Seitz, 2012) or multiplicative capabilities (Gassmann & Enkel, 2004) but have a different purpose. Desorptive and multiplicative capabilities are mainly relevant to outbound open innovation and external knowledge exploitation (Lichtenthaler & Lichtenthaler, 2009). The routines and practices underlying the enabling capability are aimed at transporting sufficient internal knowledge to external partners in order to facilitate the reflux of relevant information and external support for knowledge application within the company. Despite their outbound direction, enabling capabilities "enable" inbound open innovation. As such they may result from the same but equally from different routines and practices than other outbound capabilities. Differences may have consequences for the structure of interaction with external partners. In any case, however, they are similar to multiplicative and relational capabilities (Dyer & Singh, 1998; Gassmann & Enkel, 2004), as enabling external contributions involves codification and sharing internal knowledge, to the extent that this is possible in a time-limited innovation project. Through the deployment of enabling capabilities, companies seek to facilitate external contributions by conveying internal expectations and requirements of the new technology, but also information relating to knowledge on hard and soft organizational issues that goes beyond the technological and legal specifications necessary for outbound innovation (cf. Lichtenthaler & Lichtenthaler, 2009). Enabling capabilities are particularly important for open process innovation, because the innovation outcome is commercialized within the company and thus has to fit the specific company's expectations as well as its tacit and tangible requirements. At the

outset of interaction, external partners may be unaware of internal process and relationships, or even the organizational values. Yet, these may significantly affect process innovation (Khazanchi et al., 2007). In this context, the results suggest that the enabling capability is necessary throughout the entire lifecycle and for any form of external contribution.

Proposition 14: *Companies require the capability to enable external contributions in time-limited technological open process innovation projects, which involves practices to share sufficient information yet protect critical knowledge.*

7.4.3   Managing open process innovation as a dynamic capability

The results document the motivation for interaction with external partners and how companies manage these interactions. To interact and benefit from interaction companies, require certain capabilities, which they deploy at the different stages of the innovation lifecycle in order to absorb external knowledge and enable external contributions. Companies have to recognize, assimilate, transform, and exploit knowledge. This way they can obtain direct contributions to technological change but also indirect contributions to other process innovation components. Managing the deployment of these capabilities requires a higher-order innovation management capability (Robertson et al., 2012). The results suggest that managing open process innovation is such a capability, as it enables companies to deploy absorptive capabilities gradually across the innovation lifecycle. Managing open process innovation can be considered as a dynamic capability because it enables companies to deploy relevant absorptive capabilities dynamically and develop new internal resources, processes, and capabilities.

Dynamic capabilities: Dynamic capabilities enable companies to repeatedly change their processes and resources (Eisenhardt & Martin, 2000; Teece, 2007). Organizational processes are important drivers of competitive advantage. Yet, they do not necessarily meet the criteria for sources of sustained competitive advantage as posited by the resource-based view (cf. Barney, 1991). Process technologies become obsolete as new technologies emerge. Moreover, a company's processes are not inimitable and other companies may develop similar processes. To stay competitive, companies need to reconfigure and advance their resource base and innovate their processes. According to Teece (2007) capabilities are dynamic when they enable a company to "integrate, build, and reconfigure internal and external competencies [and resources] to address rapidly changing environments" (p. 516). Unlike regular capabilities, they do not only result from the application of resources and competences but are dynamic as they alter and reconfigure a company's resource base (Eisenhardt & Martin, 2000). They include "many well-known processes such as alliancing, product development, and strategic decision making...that bring new resources into the firm from external resources" (Eisenhardt & Martin,

2000, p. 1116). Dynamic capabilities are necessary to overcome rigidities resulting from static resources and competences (Eisenhardt & Martin, 2000; Teece et al., 1997; Teece, 2007). Against this backdrop, the results of the present thesis suggest that the management of process development and implementation qualifies as a dynamic capability.

Open process innovation as a dynamic capability: According to Piening and Salge (2015, p. 94) "process renewal or innovation is by definition the central function of dynamic capabilities" as companies create, install, and replicate new operating routines. The present study advances this perspective by suggesting that in fact the management of open process innovation is an inherently dynamic capability, as it involves the absorption of new, external knowledge to develop new internal resources, processes, and capabilities (cf. Eisenhardt & Martin, 2000). Managing the deployment of capabilities and the involvement of external partners for process development and implementation is a dynamic capability, as companies deploy the capabilities to absorb and apply external knowledge and technology in order to alter internal resources, process, and create new capabilities. As documented in the present study, managing open process innovation comprises at least three functions that are key to the dynamic capability constructs as proposed by Teece (2007): sensing and shaping opportunities and threats by establishing processes to tap into external science and technology (the present study identified routines for the recognition and exploration of new knowledge); seizing opportunities by building capacity to absorb external knowledge (the present study demonstrated the relevance of having a task force to structure of interaction with external partners); managing threats and reconfiguration when integrating know-how from outside and inside the company, including coping with knowledge leakage and developing governance mechanisms "to assist the flow of technology while protecting intellectual property rights from misappropriation and misuse are foundational to dynamic capabilities in many sectors today" (Teece, 2007, p. 1139) (The present study showed how companies manage knowledge sharing and protection by adjusting the openness towards external partners across the innovation lifecycle). Finally, the present study investigates the capabilities for open process innovation within a specific, yet limited scope. More specifically, the study focuses on those capabilities that organizations enact through the routines and practices of process innovation task forces. This perspective is important because task forces assume a central gatekeeper's role in open process innovation. They manage the interaction with external partners and translate external knowledge for different internal stakeholders (Cohen & Levinthal, 1990). At the same time, this shows where in the company these capabilities are located. From the dynamic capability perspective the findings suggest that a company's ability to manage open process innovation is of critical relevance to enhance and sustain competitive advantage amidst changing environmental conditions (Eisenhardt & Martin, 2000; Teece, 2007).

Proposition 15: *Managing open process innovation is a dynamic capability, as companies manage the dynamic deployment of absorptive capacities across the innovation lifecycle to reconfigure existing resources, processes, and capabilities through the absorption and application of external knowledge and technology to compete in a dynamic environment.*

7.4.4 Key findings on the deployment of absorptive capabilities for open process innovation throughout the innovation lifecycle

The previous sections discussed the deployment of absorptive capabilities for open process innovation throughout the innovation lifecycle. The key insights from this discussion can be summarized as follows.

Deploying relevant routines throughout the innovation lifecycle: The present study finds that a company's capacity for open process innovation results from a set of absorptive and "enabling" capabilities, by which the company facilitates knowledge and technology transfer. Companies absorb external knowledge gradually and use different routines and practices to manage knowledge and technology transfer for direct and indirect external contributions across the innovation lifecycle and address the specific requirements of different lifecycle stages. The nature of these practices by which companies deploy absorptive capabilities changes from conceptual to more practical efforts. In this context the study also identified the need for a specific capability to enable contributions by external partners.

Dynamic capabilities: The discussion also brought forward the argument that the management of open process innovation is actually an inherently dynamic capability, as it involves managing the absorption of new, external knowledge and technology to reconfigure existing resources and competencies and enable new internal processes, and capabilities. The study presented evidence to show that process innovation task forces are critical enactors of this dynamic capability.

8   Concluding remarks: contributions, implications, and limitations

The purpose of the present thesis was to develop theoretical constructs that capture the mechanisms governing open process innovation throughout the innovation lifecycle. The study investigated the motivation and openness of large manufacturing companies for external contributions to different process innovation components throughout the innovation lifecycle. The study accounted for the role of knowledge sharing and protection, the deployment of absorptive capabilities to facilitate open process innovation, as well as for contextual conditions such as project scope and the type of process a company develops. Against this background the thesis contributes to the literature on open innovation and open process innovation in particular.

Previous literature on open innovation has mainly focused on product innovation, whereas open process innovation has been neglected (Huang & Rice, 2012; Huizingh, 2011; Terjesen & Patel, 2014). Although several studies have addressed external contributions to process innovation at the aggregate company-level, few studies address open process innovation as an operational problem at the level of different stages within the innovation lifecycle (Rönnberg-Sjödin & Eriksson, 2010; Stock & Tatikonda, 2004). Previous studies on this subject do not, however, account for several important insights from the antecedent literature on process innovation, open innovation, and open process innovation. The present study identified key insights from these streams of literature to develop a research framework and address several knowledge gaps in the literature on process innovation, open innovation, and open process innovation in particular. In particular these knowledge gaps relate to external contributions to different process innovation components, openness as the adjustment of search breadth and depth, managing knowledge sharing and protection, and the routines underlying the capabilities for knowledge absorption.

Following from the investigation at the lifecycle stage level and at the aggregate lifecycle level, the thesis developed theoretical constructs of key mechanisms governing open process innovation. These constructs relate to external contributions to technological change and the determinants affecting them, the role of management consultants in providing methodological guidance in broad scope projects, and the indirect nature of external contributions to process innovation components other than technological change. Furthermore, the findings identify knowledge absorption for process innovation as occurring gradually as companies deploy absorptive capabilities in form of different observable routines throughout the entire innovation lifecycle. This identifies the management of open process innovation as a dynamic capability.

Figure 22 depicts the summary of the key contributions to theory as well as the implications of this study for managerial practice.
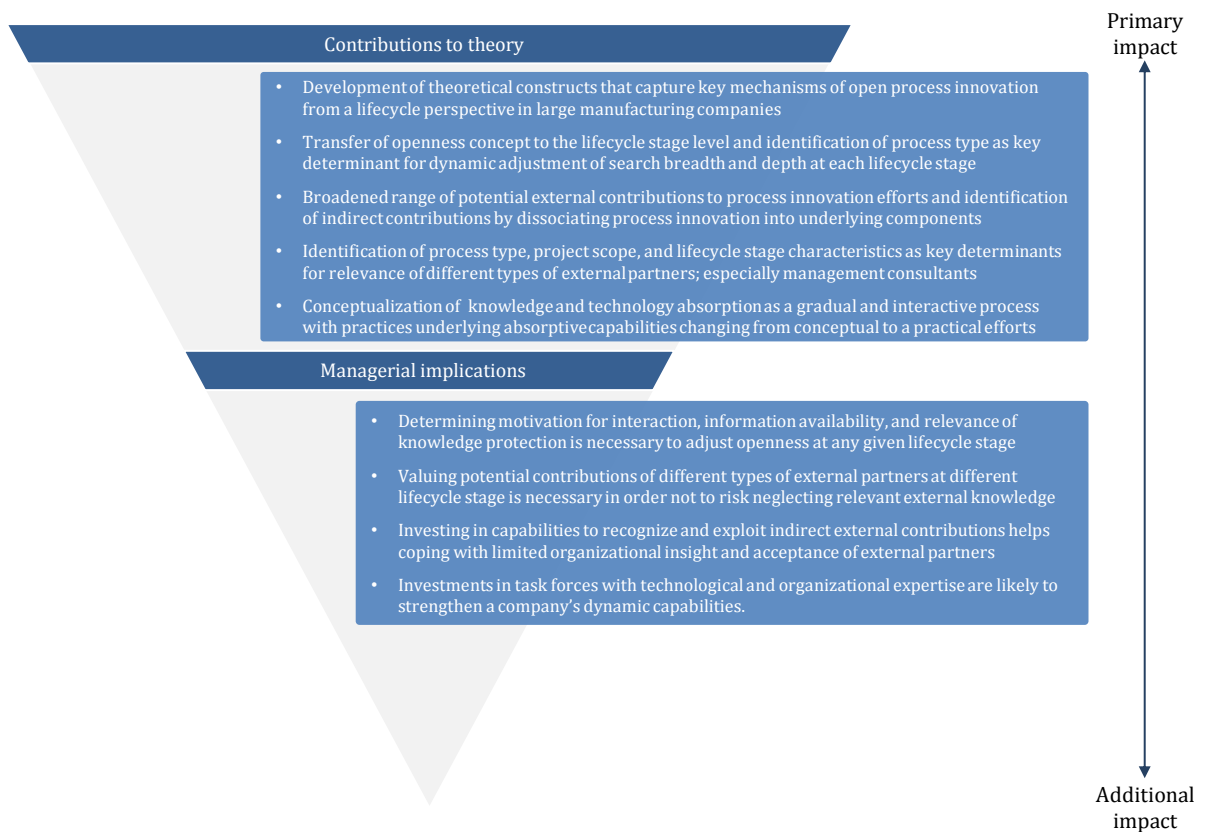
Figure 22: Summary of key contributions

This chapter concludes the thesis and summarize its contributions to theory, as well as its implications for research and managerial practice. The chapter closes with an outline of the study's limitations and an outlook for further research.

8.1 Key contributions to theory

8.1.1 Different paths of open process innovation for technological change

The study identified different forms of external contributions to technological change involving different configurations of openness. The findings suggest that the motivation for interaction, the relevance of knowledge protection, and the availability of external information at any given stage determine a company's openness and therefore which contribution the company seeks to obtain at that stage. In this context different patterns emerged for the development of enabling

and core processes. Against this background the thesis makes several contributions that are outlined in the following sections.

Openness at the lifecycle-stage level: This thesis contributes to open innovation research by investigating openness from a lifecycle perspective. Openness is a major theme in the academic discourse on open innovation (Dahlander & Gann, 2010; Huizingh, 2011). Search breadth and depth are usually accepted as the main dimensions of openness (Bahemia & Squire, 2010). Most studies investigate them at the company level (Katila & Ahuja, 2002; Laursen & Salter, 2006; Sofka & Grimpe, 2010). Other studies, suggest investigating openness at a project level (Bahemia & Squire, 2010; Horváth & Enkel, 2014; Stock & Tatikonda, 2004). However, none of these perspectives capture the dynamic nature of openness within an individual innovation project. Only few studies indicate the relevance of project stage characteristics when working with external partners for process development and implementation (Lager & Frishammar, 2010, 2012; Rönnberg-Sjödin et al., 2011; Rönnberg-Sjödin & Eriksson, 2010). Yet, these studies do not discuss openness in terms of search breadth and depth and thus leave a gap regarding the knowledge on openness at the lifecycle-stage level. The present thesis applies the concept of search breadth and depth at precisely this level and thus adds a more granular perspective to the existing open innovation literature. This perspective yields insights into opportunities and managerial challenges of open process innovation which research from an aggregated company or project-level perspective cannot capture. In this context, the study contributes new insights by constructing different forms of contributions to technological change that companies seek at different stages of the innovation lifecycle. These contributions refer to capability and capacity contributions. Adding to previous literature the study reveals a distinction between conceptual and applied capability contributions which is critical with regards to the structure of interaction. Prior research has implicitly referred to applied capability contributions, which require investments in close interaction (cf. Wagner & Hoegl, 2006). The present study showed that companies can obtain conceptual capability contributions from a broad number of sources without close interaction. This is critical, as it allows companies develop a basic understanding of potentially relevant external knowledge and technology before committing to a specific partner or technology. The insight that companies seek different forms of external contributions within a single project further points to the dynamic adjustment of openness and the determinants affecting the configuration of openness.

Dynamic adjustment of search breadth and depth: The study showed that companies dynamically combine search breadth and depth throughout the innovation lifecycle to focus their resources and efforts in such a way that allows them obtaining those external contributions they require to address the characteristic activities, outputs, and challenges at a given stage. The findings suggest that breadth is necessary to identify potential solutions. As

companies move from gaining an overview of potential solutions to detailed technology development and implementation they decrease search breadth. At the same time, depth is necessary to understand specific solutions in detail and increases in intensity until the new process is ready for installation. Important earlier studies on openness do not consider the combination of search breadth and depth. Instead, they discuss both as separate search strategies (Laursen & Salter, 2006; Terjesen & Patel, 2014). Others argue that openness differs between individual projects (cf. Bahemia & Squire, 2010; Horváth & Enkel, 2014). The present study contributes to knowledge by providing a perspective on the adjustment of breadth and depth as a critical managerial function for knowledge and technology transfer on the lifecycle-stage level. The adjustment of openness differs, however, for the development of enabling and core processes.

Different paths for enabling and core processes: Previous studies point out that different approaches to collaboration may be relevant to open process innovation (Lager & Frishammar, 2010, 2012). Yet, they remain conceptual and do not discuss different forms of interaction in more detail. Other studies do not distinguish between breadth and depth or different types of technology (Rönnberg-Sjödin et al., 2011; Rönnberg-Sjödin, 2013). Addressing this gap, the present study revealed different patterns of motivation and openness along the innovation lifecycle depending on whether the companies reported on the development of enabling or core processes. The results document that the timing of seeking specific forms of contributions differ between the two. Mapping different paths of open process innovation across the innovation lifecycle is an important contribution to open process innovation research. Lager and Frishammar (2010, 2012) suggest that the relevance of working with external partners differs depending on the combination of different technological characteristics, such as the type of process technology (proprietary/non-proprietary), and its expected performance benefits, as well as its newness, and complexity. Furthermore, Lager and Frishammar (2010), suggest for research evaluating the relevance of interaction with external partners at different points in time, in order to understand the dynamic development of interaction throughout the operational period of process equipment. The literature prior to the present thesis has not provided such a distinction from a lifecycle perspective. The present study adapted Lager and Frishammar's call by investigating open process innovation from ideation to installation, while distinguishing between enabling and core processes.

The findings suggest that the patterns result from differences in information availability and managerial challenges of knowledge protection. The evidence indicates that external information is more readily available for standard technologies, at the beginning of the innovation lifecycle. In contrast, companies have to generate relevant information for core process technology. This incurs different combinations of search breadth and depth for the cases

of enabling and core process development at early lifecycle stages. Furthermore, the present study showed how companies adjust openness throughout the lifecycle to enable and obtain external contributions, while at the same time protecting confidential knowledge. This suggests that companies reveal knowledge about internal expectations, requirements, structures, functions, and inter-dependencies. Yet, they aim to maintain secrecy about core knowledge such as product or production specifications (cf. James et al., 2013; Milesi et al., 2013; Teece, 2007). The ambition to restrict external access to confidential information at a given stage affects openness at that stage. This finding concurs with recent assertions that the effectiveness of knowledge protection for successful open innovation is determined by the strategic application of knowledge protection rather than the strength of specific protection mechanisms (Hurmelinna-Laukkanen, 2011). Earlier technology transfer literature suggests that interaction structure has to fit the technology's characteristics (Stock & Tatikonda, 2004). This thesis presents a new perspective and argues that openness changes to match the motivation for interaction which results from the lifecycle stage objectives (as determined by activities, outputs, and challenges relating to process innovation components), and to take account for information accessibility as well as the relevance of knowledge protection, i.e. restricting external access to critical internal knowledge. The results indicate that a company's path of adjusting openness throughout the innovation lifecycle depends on the type of process it seeks to develop.

Theoretical implications: The insights into the different paths of open process innovation, provided in this thesis, have implications for scholars attempting to conduct further research in this domain. Future studies on open process innovations need to be specific about the process type companies develop and at which lifecycle stage external partners contribute. Given the results of the present study, these specifications are necessary to advance the discourse on how and why open process innovation occurs. Without such a distinction it will be difficult to draw valid conclusions about external contributions to process innovation. Future studies might, for example, underestimate the general role of external partners if they investigate core processes but fail to acknowledge that limited openness results from the deliberate protection of critical knowledge which is characteristic for core process development. Different findings would probably emerge when investigating the development of enabling processes. Likewise, future studies should account for temporal contingencies that affect motivation and openness. As in the present study, a lifecycle perspective can capture different external contributions to process innovation before, during, and after technology development (cf. Rönnberg-Sjödin et al., 2011). Studies would miss the differences between external contributions when ignoring the context that different lifecycle stages provide. Such insights are, however, critical for managers to systematically plan the interaction with external partners throughout their projects. More

differentiated insights on open process innovation will be of particular value to practitioners. This thesis thus provides a basis for the design and discussion of future research on open process innovation.

8.1.2   Process innovation components and indirect contributions

The thesis shows that direct external contributions mainly relate to technological change. However, the study identified mechanisms of indirect contributions by which companies obtain external support for organizational change and systemic impact management. Against this background the thesis makes several contributions that are outlined in the following sections.

Process innovation components: This study presented process innovation as a systemic phenomenon, which comprises the mutual adaptation of new technology and existing organization, and thus involves technological and organizational change. Previous studies on open process innovation from a lifecycle perspective have not explicitly accounted for these process innovation components (Lager & Frishammar, 2010, 2012; Rönnberg-Sjödin et al., 2011; Rönnberg-Sjödin & Eriksson, 2010). The findings of the present study show that it is important to consider these components in order to develop a more differentiated picture of the mechanisms underlying open process innovation. The present study found that external partners contribute directly to technological change. Contributions to other process innovation components are limited and occur indirectly. Furthermore, the study describes the activities, outputs, and challenges that characterize lifecycle stages in terms of the process innovation components that constitute them. Earlier studies on process development and implementation mainly focus on important activities and sequences in the process innovation lifecycle (Clark & Wheelwright, 1993; Gerwin, 1988; Hayes et al., 2005; Kurkkio et al., 2011; Lager, 2011; Voss, 1992). Although they occasionally refer to specific process innovation components they do not investigate them in a coherent way. The present study thus adds to previous research by adopting a full lifecycle perspective on the investigation of the content of these components.

Limited direct contributions: The results show that the companies in this study obtain noticeably limited external contributions to organizational change throughout the entire innovation lifecycle. This is in contrast to earlier research which suggests that external change agents are important drivers of such innovation (Birkinshaw et al., 2008; Wright et al., 2012). While earlier studies focus on managerial change, the present thesis focuses on organizational change in technological process innovation. In this context the study identifies two particular reasons for the limited involvement of external partners. Firstly, limited organizational insight impedes the ability of external actors to draw conclusions about specific organizational changes.

Secondly, limited acceptance among operators hinders external contributions towards planning and implementing organizational change.

Indirect contributions: The insights of this thesis also respond to earlier studies which propose that limited organizational insight constrains opportunities for open process innovation beyond external technology acquisition (Huizingh, 2011). The present study reveals indirect external contributions to components of process innovation other than technological change. More specifically, the results showed that external technological and methodological knowledge also enables task forces to draw conclusions about organizational change, systemic impact, and therefore also mutual adaptation. Indirect contributions are easy to overlook but important nonetheless. They provide information that generates new knowledge among company stakeholders which in turn enables them to create further change. The insights into indirect contributions as presented in this study differ from other references to indirect contributions in the literature (Cassiman & Veugelers, 2000; Gnyawali & Park, 2011; Grimaldi & von Tunzelmann, 2002; OECD, 2009; Ornaghi, 2006; Perkmann et al., 2011; Salman & Saives, 2005). In this respect the study provides three necessary but not necessarily sufficient conditions for indirect contributions. It will be a task for future research to clearly define the scope of indirect contribution and develop measurement tools. The findings of this study can be used a starting point for future efforts to understand the value of indirect contributions.

Theoretical implications: It was possible to identify indirect contributions and distinguish them from direct contributions to technological change because the study explicitly distinguished process innovation components. This shows that different components have to be considered to understand open process innovation in more depth. Applying the components advanced in this study can guide further empirical research on open process innovation to be more specific on the locus of external contributions, in other words: to which component of process innovation do external partners contribute?

8.1.3 Different types of partners and relevance of management consultants

This study investigated contributions by different types of external partners. The results suggest that management consultants may be important contributors to process innovation when providing methodological support during early lifecycle stages in projects with a broad scope. Against this background the thesis makes several contributions that are outlined in the following sections.

Different types of partners: While the present study concurs with earlier studies that technology suppliers are most prominent for open process innovation (Frishammar et al., 2012; Reichstein & Salter, 2006), it provides empirical evidence of contributions by other external

actors than technology suppliers. Previous studies of open process innovation from a lifecycle perspective have focused on the interaction between buyers and suppliers of processing equipment but do not capture contributions by other types of partners (Lager & Frishammar, 2010, 2012; Rönnberg-Sjödin et al., 2011; Rönnberg-Sjödin & Eriksson, 2010; Rönnberg-Sjödin, 2013). The present study identifies additional contributors during the early, conceptual stages of process innovation, which precede the physical development and implementation work. Companies may engage with a variety of external technology experts to generate an overview of potential solutions, before increasingly focusing on the interaction with selected technology suppliers. Against this backdrop, the present study puts contributions of earlier research on technology supplier involvement for process innovation (e.g. Athaide et al., 1996) into the context of different lifecycle stages.

Management consultants: The results show that consultants provide methodological support at early lifecycle stages. Methodological support includes a range of contributions that neither relate to technological or organizational change directly but instead provide companies with tools and support for the identification and evaluation processes. Earlier conceptual literature has pointed out the contributions of consultants to process innovation (Bessant & Rush, 1995; Carrillo & Gaimon, 2002). Other studies hint at the role of external consultants in open process innovation but do not further elaborate on it (Frishammar et al., 2012; Linton, 2000). This thesis presents empirical evidence to put earlier insights into context of specific lifecycle stages and projects and finds that they are particularly relevant in projects with a broad scope. By including management consultants as important external partners in open process innovation the present study extends earlier research. The contributions of management consultants are often associated with the diffusion of new operational practices across industrial boundaries (Dawes et al., 1997; Hislop, 2002; Reichstein & Salter, 2006). In this respect, previous research finds that the interaction with consultants is not an inducement for companies to become process innovators (Reichstein & Salter, 2006). The present study, however, shows that once companies initiate process innovation projects, external management consultants can contribute to process development by providing methodological guidance at the early stages. This shows that management consultants provide methodological contributions rather than support that directly relates to process innovation components (Bessant & Rush, 1995). Methodological contributions set the frame for further development work and are therefore necessary at the early stages. The results further show that consultants mainly require structural knowledge. This is unlikely to threaten a company's core knowledge base. Accordingly, knowledge protection is not particular a managerial challenge. For managers this is important because it shows that there are opportunities to limit the involvement of management consultants to specific stages in specific projects. This allows cutting the costs of working with consultants, when involving them

strategically at the early stages. The study suggests that management consultants mainly contribute to projects with a broad scope. In the present study such projects all refer to the development of enabling processes. However, this may be a result of the limited data available for this study. The reports on core processes all have a focus on narrow scope projects and did not allow for further insight into broad scope core process development.

Theoretical implications: The open process innovation literature has paid very little attention to external partners other than technology suppliers. By documenting the involvement of different types of external partners the present study shifts attention towards the specific contributions by a broader range of external knowledge sources that can shape a company's process innovation efforts. Furthermore, the present study provides empirical evidence to suggest that the relevance of different external partners depends on the lifecycle stage that is being considered. The relevance of external partners throughout the innovation lifecycle may differ between the development of enabling and core processes as well as between broad and narrow scope projects. These insights enable a more comprehensive approach to research on external contributions to process innovation. For example, it may be easy to miss contributions by consultants or research institutes when only considering the development stages of new process technology, but not the early conceptual stages.

8.1.4   Deployment of absorptive capabilities for open process innovation

The study contributed to previous literature on open process innovation from a lifecycle perspective, by providing a discussion of capability deployment during process development and implementation. The results of the study lead to the outline of a specific, gradual, and interaction absorption process and the changing nature of the practices by which companies deploy absorptive capabilities at different stages of the innovation lifecycle. The thesis argues that the management of open process innovation itself is a dynamic capability. The following sections summarize the contributions makes with regards to absorptive capacity and open innovation.

Capability deployment: The thesis illuminated the process of deploying absorptive capabilities throughout the innovation lifecycle in context of open process innovation. By mapping central routines and practices by which companies deploy of absorptive capabilities across the innovation lifecycle, the thesis contributes to the conceptualization of absorption capacity and proposes a process of how companies actually absorb new knowledge (Lerch et al., 2012; Lewin et al., 2011; Müller-Seitz, 2012). In particular, the results in the present study described a gradual knowledge absorption process in which managers adjust the routines and practices underlying the absorptive capabilities to address the specific requirements of different lifecycle

stages. As the thesis focuses on the case of open process innovation, where the mutual adaptation of new technology and existing organization is of central importance, capabilities for the assimilation of new knowledge as well as for the transformation of existing knowledge emerged as particularly relevant. Accordingly, the thesis argues that knowledge assimilation and transformation occur conjointly and throughout the entire lifecycle, rather sequentially, as suggested by earlier research (cf. Zahra & George, 2002). Furthermore, the thesis argues that the nature of these capabilities evolves from a conceptual focus which is influenced by recognition and exploration during the early stages to a more practical focus during the later stages, which is influenced by capabilities with a focus on application such as adaptive and integrative capabilities, as well as exploitation. Finally, the study also identifies the need for an "enabling capability", which is complementary to yet distinct from earlier constructs like desorptive or alliance management capabilities (Dyer & Singh, 1998; Gassmann & Enkel, 2004; Lichtenthaler & Lichtenthaler, 2009).

Dynamic capability perspective: The findings present the deployment of these capabilities as a dynamic capability. Dynamic capabilities are necessary to overcome rigidities that result from static resources and competences (Eisenhardt & Martin, 2000; Teece et al., 1997; Teece, 2007). According to Piening and Salge (2015, p. 94) "process renewal or innovation is by definition the central function of dynamic capabilities" as companies create, install, and replicate new operating routines. The present study advanced this perspective by suggesting that actually the management of open process innovation is an inherently dynamic capability, as it involves managing the absorption of new, external knowledge to develop new internal resources, processes, and capabilities. The study presented evidence to show that process innovation task forces are critical enactors of this dynamic capability.

Theoretical implications: Regarding the deployment of absorptive capabilities and the dynamic adjustment of the practices underlying these capabilities, the thesis highlighted the critical role of the internal task force. The deployment of capabilities by the task forces as documented in this study strengthens the perspective that a better understanding of knowledge absorption processes can be developed by studying the underlying practices and routines by which companies absorb new knowledge (cf. Lewin et al., 2011). At the same time the findings suggest that task forces, as described in this study, are central loci for dynamic capabilities as they manage the dynamic deployment of absorptive capabilities throughout the innovation lifecycle. This suggests that investigating the practices of particular organizational stakeholders bears the potential to understand absorptive capacity and dynamic capabilities in more depth.

8.2 Implications for managerial practice

This thesis provided insights into rationale behind the motivation for interaction and openness at the project-stage level in open process innovation. These insights are of relevance to process innovation task forces as well as to higher-level decision makers responsible for assigning resources to process development and implementation projects. The following sections elaborate on the study's managerial implications in more detail.

8.2.1 Selecting appropriate paths for open process innovation

The study showed that companies can dynamically adapt openness (i.e. search breadth and depth) throughout the innovation lifecycle. For managers this is particularly important because it clearly shows that openness is not just a strategic objective but an operations level construct, which needs to be enacted at a practical level. In order to determine the most adequate form of external contribution towards technological change at a given stage, managers and decision makers need to determine the motivation for interaction, the availability of external solutions, and the relevance of knowledge protection at that stage. Against this background, the present study pointed out the differences between conceptual and applied capability contributions as well as capacity contributions. This implies that managers need to be aware of the type of process they develop, in order to make adequate plans for the interaction with external partners. Managers wanting to address core processes may have good reason to prioritize internally generated technological change as a means to accentuate competitive advantage with proprietary technologies. Conversely, the results suggest some justification for relatively more emphasis on organizational change as a means to leverage the benefits of externally sourced standard technology solutions when managers seek efficiency gains in non-core processes.

8.2.2 Managing knowledge protection throughout the innovation lifecycle

It is important for managers to involve external experts for the right tasks given the type of process they are working on to prevent critical knowledge leakage and loss of internal capabilities. This is also important for future technology acquisitions, because companies learn from acquisition experiences (Flowers, 2007). The present study provides an indication at what stages what type of contribution is relevant and why. While secrecy is important to protect process innovation (James et al., 2013; Milesi et al., 2013; cf. Teece, 1986) not all internal knowledge is confidential or needs to be shielded from external actors. In fact, certain information should be provided to enable external contributions. This presupposes that managers are aware of the value internal knowledge has. Evaluation programs and internal education about the value of intellectual property seem necessary. Managers also need to be

aware at which lifecycle stages access to confidential data is necessary in order to plan for work responsibility distribution and to perform tasks internally, when necessary. If sharing confidential information is unavoidable, managers should deploy protection mechanisms, such as strategic supplier relations and exclusivity in addition to legal agreements.

8.2.3 Understanding the relevance of different types of external partners, lifecycle stages and process innovation components

The study showed that technology suppliers are important partners at all lifecycle stages. Furthermore, the findings revealed that other external technology experts and management consultants may be important at early lifecycle stages. Managers need to understand the potential contributions of different external partners and at which stage of the innovation lifecycle they are relevant. Neglecting potentially relevant sources of external knowledge may impede a company's chances to recognize relevant external knowledge. On the other hand, randomly involving external partners to increase search breadth will likely increase costs and may impede a company's ability to focus resources on relevant external partners (Laursen & Salter, 2014; Terjesen & Patel, 2014). The present study documented the rationale behind involving different types of external partners along the innovation lifecycle and for different types of process innovation projects. This can serve managers as a benchmark to structure the involvement of external partners. For example, managers may want to cut costs by limiting the involvement of management consultants by only involving them strategically at the early stages of broad scope technological process innovation projects. By highlighting the role of various external partners, the present study also developed the theoretical construct of indirect external contributions for process innovation. The study suggests for managers to look beyond direct contributions to technological change and become aware of the value that indirect contributions may have. Obtaining indirect contributions presupposes that the task force has the capability to translate external information to facilitate its internal application. Managers should therefore invest in building and developing such task forces.

8.2.4 Investing in task forces

The study mainly adopted the perspective of process innovation task forces. Nevertheless, the results are also of interest to higher-level managers. The results showed that managing open process innovation requires the gradual deployment of capabilities for knowledge absorption including enabling external contributions. The thesis suggests that managing open process innovation is a dynamic capability and therefore of critical relevance to sustain competitive advantage (cf. Eisenhardt & Martin, 2000). Task forces enact the management of open process innovation. Managers need to understand the important role a task force has in absorbing

external knowledge and technology, enabling external contributions, and facilitating internal knowledge dissemination. The management of process innovation requires a task forces to have not only strong technological receptivity (cf. Ettlie et al., 1984: technical specialists) but also detailed organizational insights. Furthermore, the results strongly suggest that task forces need to be able to dynamically adjust routines and practices from the conceptual to the practical level in order to gradually absorb new knowledge and technology throughout the innovation lifecycle. This also entails the ability to communicate with a variety of different external experts, as well as with internal stakeholders at different hierarchical levels and with potentially diverging interests. Given the central importance of task forces to facilitate open process innovation, it seems to be of critical importance to invest in task force development. This promises to strengthen companies in achieving and sustaining competitive advantage amidst ever-changing competitive environments. Substantial investments in human capital and development are required to develop an effective task force. This also requires ensuring that task force members are provided with sufficient hierarchical power (Herrmann et al., 2006; Meyers et al., 1999). In this regard it remains for further research to understand in more detail, how to develop such teams.

8.2.5 Mapping and benchmarking tool

Practitioners responsible for process development and implementation can use the conceptual framework developed in this study as well as the constructs that this thesis presented as tools for planning and structuring process innovation projects. Previous literature suggests that knowledge and technology transfer is often unstructured and ad-hoc (Stock & Tatikonda, 2004). The present study provides a tool to help practitioners address this issue. The generic lifecycle stages advanced in this thesis can be adapted to company specific projects. This allows companies to map their activities across these stages and to identify relevant stage contingencies that may affect the interaction with external partners. In this respect, the study encourages practitioners to assess the scope of their innovation projects and the relevance to core operations. This will help companies determine an appropriate path of adjusting breadth and depth and obtaining adequate forms of external contributions throughout the innovation lifecycle. The framework also specifically advises managers to account for different process innovation components, rather than just obvious technological change. This will help to identify opportunities to obtain indirect contributions and search from a broader range of external knowledge sources, if feasible.

8.3 Limitations of the study and avenues for further research

The present study has several limitations that have to be addressed. These limitations relate to how far the findings of case-based research design can be generalized, as well as to the use of retrospective data, and the application of a linear lifecycle. The following sections discuss these limitations in more detail and suggest avenues for further research.

Generalizability: The present study identified themes and developed constructs of open process innovation. In particular the study focused on large manufacturing companies. The study involved a selection of five successful companies from different manufacturing industries. The findings build on the accounts of experienced, knowledgeable representatives within these companies. The case-based research approach was most useful to explore open process innovation as an organizational phenomenon, given the objective of developing theoretical constructs of open process innovation from a lifecycle perspective. The research approach suited the exploratory purpose of the study, especially due to the little amount of prior work. Although important conceptual constructs were initially suggested to guide data collection and analysis, it was not clear at the outset of the study what the important themes, constructs, and boundaries of the phenomenon would be. Furthermore, the study addressed a complex managerial challenge and asked "how-and-why" questions to understand the underlying motivations for and structures of interaction between the companies and their external partners. Against this background, the case-based approach was considered most appropriate and useful for the present study (Eisenhardt & Graebner, 2007; cf. Yin, 2003).

The small number of cases and qualitative nature of the data on which this study is based limit the statistical generalizability of the findings. The study builds on the experiences of knowledgeable experts in successful companies across a variety of sectors. The reports that informed this study involved accounts of opportunities and challenges of working with external partners for process development and implementation. Cross-case analysis and replication logic (literal and theoretical) were applied to elicit analytically generalizable insights (cf. Eisenhardt, 1989; Yin, 2003). These measures increase the external validity of the different themes and constructs identified in this study. No claim can be made, however, that the study has identified best practices, as the analysis did not compare different levels of innovation success.

The data analysis applied replication logic. Findings were first replicated across similar cases and then contrasted against different ones. This helped to identify differences between the development of enabling and core processes and between broad and narrow scope projects. However, the fact that there was one case of core process development (TEC) remains a limitation. This limitation is to some extent mitigated by corroborating evidence that additional

information from the other companies yielded. The research has also only focused on narrow scope core process innovation. Yet, there may be core process innovation projects with a very broad scope. Such projects may entail more organizational change than captured in this study. Such projects may involve management consultants and other partners. It is for further research to address this gap.

The present study aimed at analytical generalizability. Yet, the study emphasizes the complementarity between exploratory studies and large scale statistical research as discussed by Eisenhardt and Graebner (2007). The present study's findings provide the basis for further deductive research. Such research should specifically account for contingencies of process type and project scope. Moreover, it should account for different process innovation components and different lifecycle stages. This would enable large scale, deductive research to test the open process innovation paths as documented in the present study. A different approach would involve in-depth, participatory case-based research to identify further routines and practices which constitute the capability to manage open process innovation.

Retrospective data on general experiences: The study built on retrospective data on general experiences of managing open process innovation rather than specific, individual projects. The use of such data could be regarded as a limitation because it does not provide an in-depth investigation of individual projects. Furthermore, retrospective data involves the risk of ex-post sense-making, selective memory, or misrepresentation by the informants, all of which constrain data purity (Eisenhardt & Graebner, 2007). However, the study's units of analysis related to open process innovation in general, rather than to a specific open process innovation project in a specific company. In this respect the experiences of the different informants provided an opportunity to tap into a rich account of experiences by various informants in different settings to inform the development of theoretical constructs that describe the mechanisms of open process innovation. Furthermore, the data set that informed this study was relatively large and aggregated multiple sources and types of data. The results underwent academic and expert review. Together these measures strengthen the validity of the findings (Eisenhardt, 1989; Riege, 2003; Yin, 2003).

Linear, generic lifecycle: For analytical purposes the present study used a generic, linear innovation lifecycle. The main ambition thereof was to provide a coherent picture of the innovation lifecycle from ideation to installation. The linear process model made it possible to structure and compare activities relating to different lifecycle stages. The lifecycle was informed by empirical literature and fit very well with the reports by the task forces. Nevertheless, it is likely that at the a sub-stage level the innovation lifecycle is more complex than depicted in this study and perhaps even chaotic (cf. McCarthy et al., 2006). This may affect a company's

motivation for interaction with external partners as well as the structure of interaction. Iterative loops within the same stage may, for example, increase the importance of external partners to solve emergent issues, after companies have repeatedly failed to solve them internally. Further research could therefore use the study's results as the basis for further investigation of open process innovation using non-linear lifecycle models.

Research on further determinants: Process innovation is a complex phenomenon and comprises various internal social interactions within the company. Any study can only catch a glimpse of this innovation system and boundaries have to be drawn. This also limits the scope of the present thesis. Future research should therefore investigate further determinants affecting open process innovation. The following are several important suggestions for such studies.

- **Operators' perspective:** The present study focused mainly on the task force as a specific group within the company. Nevertheless, other internal stakeholders are critical to process innovation too (Meyers et al., 1999). Performance gaps are often identified at the operating level (Kurkkio et al., 2011). Yet, the study indicated that there animosity against external input among the operating personal is likely. Further research could try to understand in more detail how external change contributions are received and diffused but also opposed among the operating personal.

- **Innovation radicalness:** This thesis distinguished between enabling and core processes and broad and narrow scope projects. There was no in-depth discussion the distinction between radical and incremental innovation. Yet, literature shows that innovation radicalness affects the role of external contributions towards process innovation (Reichstein & Salter, 2006). Further research could be more specific on this distinction. Given the internal application of new processes it will, however, be a challenge to categorize radicalness. What is radically new for one company may be well established in another. Conversely, incremental changes in one company may be radically new to outsiders. The experiences with a specific process or technology may determine whether an innovation is perceived as radical or not. Future studies need to be careful to take this into account.

- **Technological and organizational determinants:** Further research should account for technological characteristics (e.g. Stock & Tatikonda, 2004), organizational characteristics (Ettlie et al., 1984), and culture (Frishammar et al., 2012; Khazanchi et al., 2007) in more detail, to understand their implications for open process innovation at different lifecycle stages. The present study, for example, showed that large company size and heterogeneous organizational structures necessitate methods and capacity for process appraisal and communication at hand. Furthermore, the study found that there

was a general animosity against organizational change, which limited the involvement of external partners in this area. The specific technological and organizational characteristics deserve more investigation than could possibly be covered by the present study and is therefore left for further research. Furthermore, the cost of knowledge and technology acquisition may moderate the approaches to open process innovation and should be investigated in more depth.

- **Network level:** The study focused on the interaction between companies and their direct external partners. However, it is likely that companies operate as members of broader industrial networks, in which suppliers interact with competitors and further suppliers. This may further affect the relevance and managerial challenge of knowledge sharing and protection. Further research could move beyond the dyad-level and investigate open process innovation from a network perspective.

- **Cultural dimension:** The present study emphasized the importance of interaction between different internal and external stakeholders of the innovating company. These interactions unfold within a specific cultural setting, which is determined by dimensions such as, for example, the society's culture, values of its members, power distance, uncertainty avoidance, or masculinity (cf. Hofstede's theory on cultural dimensions). In this regard it is a limitation of the study that the focus of investigation was set on Western European companies and their German operations. The German context is characterized by a specific configuration of cultural dimensions which may significantly differ from other cultural settings. Therefore, further research should assess the impact of cultural dimensions on the mechanisms of interaction in technological open process innovation and contrast the findings of the present study with insights on open process innovation in other cultural settings.

- **Capability development:** The study suggests that absorptive and enabling capabilities are necessary to manage open process innovation. The study investigated these capabilities by identifying observable practices and routines (cf. Lewin et al., 2011). The study suggested for managers to invest in the capabilities of their task forces. In this regard it is important for further research to understand how to develop these capabilities.

Appendices

Appendix 1: Characteristics of large companies

Characteristics of large companies

Introduction: Company size can be measured in different ways, such as the number of employees, annual turnover, total assets, or a combination thereof. Pavitt (1991) considers a company to be large when it has around 10,000 employees. The Schumpeterian view suggests that large companies are generally more innovative than small companies. In any case large companies provide solid grounding for research on innovation. They comprise certain characteristics that make systematic innovation management unavoidable. The following sections briefly outline several key characteristics of large companies.

Higher rates of process innovation than small companies: Schumpeter hypothesized that large companies are more capable of creating innovation than small companies. Many scholars have addressed the Schumpeterian hypothesis. Company size is one of the most frequently studied innovation determinants (Damanpour & Aravind, 2006; Reichstein & Salter, 2006). Research on the effect of company size on innovation adoption has also addressed the distinction between product and process innovation. Generally there is consent in literature that large companies invest more of their budget in process innovation than small companies. Larger companies are more prone to process innovation as they are more likely to possess the resources and infrastructure to acquire new equipment and amortize new processes (Reichstein & Salter, 2006; Vossen, 1998). Furthermore, large companies may realize synergies between well-developed skills and competences in various functions that enable them to exploit innovation more readily. This enables them to exploit their existing products in the market through lower production costs (Cabagnols & Le Bas, 2002; Cohen & Klepper, 1996). In this regard Martinez-Ros (Martinez-Ros, 2000) found that larger companies constantly adopted more process innovation than small companies. Martinez-Ros argued that the effect of size for process innovation resulted from larger access to more relevant facilities, internal capabilities and resources to create process innovation in large companies. This effect is particularly relevant for process innovation. Because of economies of scale "in larger firms even processes that contribute a small proportion of a firm's output may justify the adoption of innovations on the basis of economies of scale or through production critical masses at which innovation becomes efficient" (Cooper, 2005, p. 499). Accordingly, Bertschek (1995) found that company size (number of firm's employees relative to total industry employment) only had a significant effect on process but not on product innovation (see also: Fritsch & Meschede, 2001). Several

meta-analyses of company size and innovation adoption corroborate these insights (Damanpour, 1992; Camison-Zornoza et al., 2004). Large companies are therefore more likely than small companies to provide a rich set of experiences of managing process development and implementation.

External collaboration and open innovation: The significant resource endowments and reputation enables large companies to 'establish comprehensive external networks to access knowledge and technology (Vossen, 1998). In such networks large firms are able to access external capital more readily. Although some large companies may have the resources to conduct significant research internally, many companies are driven to reduce costs and leverage external sources of innovation (Philbin, 2008). It has been suggested that large companies usually emphasize inbound processes (Mortara & Minshall, 2011). With regards to process innovation, it is frequently posited that companies acquire process equipment from external sources (Huizingh, 2011; Lager, 2011; Reichstein & Salter, 2006). Large companies often seek to install more formal modes of collaboration (e.g. alliances with contractual agreements). As they tend to be the more powerful partner in collaborations with smaller companies they can impose more rigid, controlled, and formal interaction (Chiesa & Manzini, 1998). Due to the quantity of collaborations that large companies usually engage in "[they] shy away from [exclusive agreements] because tracking the myriad constraints increases exponentially with the number of signed exclusive agreements" (Slowinski et al., 2006). The most frequently studied company characteristic in open innovation is firm size (Huizingh, 2011). While it seems currently accepted that open innovation is currently mainly adopted by large companies, small firms increasingly leverage external collaborations to overcome limited resources and market reach (Lee et al., 2010). Nevertheless, large companies have better suited capabilities and resources to establish and maintain relationships with multiple external partners and enforce intellectual property rights. It is, therefore, not surprising that across various countries and industries inbound and outbound open innovation is mainly adopted by large companies (Bianchi et al., 2011; Keupp & Gassmann, 2009).

Risk avoiding strategies and incremental innovation: Large, mature companies have a tendency to avoid risk and uncertainty in their innovative activities in favor of less risky, short-term innovation (Dougherty & Hardy, 1996; Pavitt, 1991; Slowinski et al., 2006; Vossen, 1998). Although large companies can spread risk over a great number of operations, markets, or products, existing businesses provide a sense of certainty, while new business ventures require long-term investment, flexibility and creativity, thus invoking high levels of uncertainty (Dougherty & Hardy, 1996; Vossen, 1998). Stakeholders may, however, value short-term perspectives. Stakeholders, in particular shareholders, in large companies may therefore hinder more radical and uncertain innovation by pressuring decision makers to adopt more short-term

technology policies, whose outcome is more evident and delivers short-term financial returns (Vossen, 1998). Moreover, established cultures and organizational routines often favor more incremental, low risk projects (McDermott, 1999). In large, mature companies, technology champions may be too busy or unable to generate the necessary interest, attention, or budget from decision makers to initiate a particular innovation idea (Dougherty & Hardy, 1996). In conclusion, it is a particular challenge in large companies to generate acceptance for change.

Complex, formal, decentralized organizational structures: Large companies' organizational structure is a further important determinant for innovation adoption. Ettlie et al. (1984) in a sample of 192 firms in the food processing industries, found strong support for the proposition that "large organization size promotes more structural complexity, formalization, and decentralization", which in turn favors less radical and more incremental technological innovation strategies. Complexity arises from the coordination of innovation efforts across a diverse set of organizational functions and departments. Pavitt (1991) suggests that large companies usually pursue diverse technological activities they are comprise various functions, departments, and divisions. Large companies usually possess significant functional expertise and specialized labor (Vossen, 1998). Such resources and competences are, however, distributed across a broad range of functional and departments. In order to be innovative, companies need to be able to "combine these largely technological competences into effective units for identifying and developing innovation" (Pavitt, 1991, p. 43). Large companies thus face the challenge of managing complex structures emerging from departmentalization. This can for example result in slow decision making processes and inefficient internal communication and coordination (Vossen, 1998). As a large number of people are involved in decision making managerial co-ordination may be inefficient and lack flexibility (Vossen, 1998). Formal decision making is therefore often necessary to cope with organizational complexity. Large companies are therefore often very bureaucratic and rigid. Rigid organizational structures can hinder the process of exploiting potential technological opportunities (Vossen, 1998).

Summary: Large companies provide a rich context for the study of open process innovation. They are likely to make substantial investments in process innovation. Furthermore, they invest in external collaborations and inbound open innovation. Yet, managing process development and implementation in these companies is a challenging managerial task. There is likely a strong preference for short-term orientation and risk-avoiding strategies paired with reluctance to accept change. Moreover, complex organizational structures and decision making processes make it difficult to coordinate and promote change.

Appendix 2: Technological innovation attributes

Attribute	Definition	Key reference(s)
Relative Advantage	The degree to which a technology is perceived as superior to the technological status quo as described along relevant categories.	Rogers (2003); Tornatzky and Klein (1982)
Compatibility	The extent technology is perceived as consistent with existing practices, resources, and needs of the organization. This involves concern for complementarity and conflict with other components of an affected process.	Gerwin (1988); Tornatzky and Klein (1982); Rogers (2003)
Complexity	The extent technology is perceived as difficult to understand and use, including the degree to which it is perceived to be novel or sophisticated.	Gerwin (1988); Rogers (2003); Tyre and Hauptmann (1992)
Communicability / Observability	The extent, to which the technology can be specified, expressed, articulated, or made visible to other members within the organization.	Rogers (2003); Tornatzky and Klein (1982)

Appendix 3: Case selection criteria

Criteria	Details	Illustrative references
First order criteria		
Large companies	Comprise 10,000+ employees	▪ Pavitt (1991)
	Are likely to invest in process innovation and possess better process innovation capabilities than small and medium sized enterprises	▪ Reichstein and Salter (2006)
	Provide a rich setting for studying innovation management because process change needs to be coordinated across relatively more complex organizational structures than in small and medium sized companies	▪ Vossen (1998) ▪ Pavitt (1991)
Manufacturing industries	Develop process innovation in conjunction with new products but also independently of them	▪ Martinez-Ros (2000)
	Production intensive manufacturing companies build on process innovation for organizational competitiveness	▪ Pavitt (1991)
	Frequently obtain technologies from external sources	▪ Pavitt (1991)
Second order criteria		
Type of process	Distinction between core and enabling processes Core processes are directly related to the creation of the primary value for customers Enabling processes are important organizational processes but not directly related to a company's primary activities; instead they facilitate them	▪ Armistead and Machin (1997) ▪ Smart et al. (1999) ▪ Lager and Frishammar (2010)
Project scope	Distinction between broad and narrow project scope Broad scope projects include technological and organizational change. Involve a focus on one or more technologies. Involve organizational change across multiple organizational departments and functions and possibly multiple sites at the same time. Narrow scope projects include mainly technological change and require only minor organizational change coordination Involve only one technology. Are limited to a specific department or setting. Involve organizational change which are limited to a specific department or setting and do not include simultaneous roll-out in various heterogeneous functions, departments, or locations.	▪ Suggested by author

Appendix 4: Case selection process

	Objective	Actions taken	Output
Theoretical criteria	Establish sampling criteria	Literature review	Sampling criteria
Industry scan	Compile list of potential companies	Online, newspaper and archival research → Leverage industrial contacts	List of potential companies
Contact	Confirm cases	E-Mail contact	Confirm, Rejection, or Referral
Selection	Confirm interviewees	Discussion of topic with project champion → Approach of relevant interviewees by project champion	Identification of relevant interviewees

Appendix 5: Interview guide I (January and February 2013)

Interview questions in German (G) and English (E)

Introduction

G   Bitte geben Sie mir einen kurzen Überblick Ihrer Aufgaben im Bereich Prozessentwicklung.

E   Please give me a brief overview of your tasks and responsibilities relating to process development.

Ideation: Mutual adaptation

G   In wie fern wird bei der Suche nach neuen Technologien (Maschine, Software, Methode) schon darüber nachgedacht, wie später die neue technologische Lösung und das bestehende Unternehmen aneinander angepasst werden müssen?

E   To what extent do you consider the adaptation of new technology and existing organization during the ideation stage?

Ideation: Technological change

G   Wenn man nach verschiedenen technologischen Lösungen sucht, welche Rolle spielt es dabei, wie komplex die Lösung ist, d.h. wie schwer es ist, die Technologie zu verstehen, zu benutzen und auch zu vermitteln?

E   How would you describe the relevance of technological complexity in terms of understanding a technology, anticipated difficulty of use and communicability when searching for new solutions?

Ideation: Organizational change

G   In wie fern spielen Überlegungen bezüglich Veränderungen am Unternehmen schon ganz am Anfang eine Rolle, d.h. bei der Suche nach Lösungen für bestimmte Probleme?

E   To what extend do considerations of organizational change play a role during idea generation?

Ideation: Systemic impact

G   Welche Rolle spielen mögliche Folgewirkungen einzelner Veränderungen bereits in der Phase der Ideen-Findung?

E   What effect do potential systemic impacts of individual changes have on the idea generation stage?

Adoption: Mutual adaptation

G   Werden bei der Entscheidung für ein Lösungskonzept eher Anpassungen der Technologie oder des Unternehmens in Betracht gezogen? Wo ist generell die Präferenz?

E   Is there a preference for either technological or organizational changes during adoption? What is the general preference, if any?

Adoption: Technological change

G   Wie detailliert muss das neue technologische Lösungskonzept an dieser Stelle schon verstanden werden? D.h. wie genau muss klar sein, was die Technologie bieten und was von ihr erwartet werden kann.

E   How detailed does a new technology have to be understood at this stage in terms of knowing the technology's functionality and what can be expected of that technology?

Adoption decision: Technological change

G   Wie muss oder kann das technologische Lösungskonzept den Entscheidungsträgern in dieser Phase kommuniziert werden?

E   How can or must technological solutions be communicated to decision makers during this stage?

Interview questions in German (G) and English (E)

Adoption decision: Organizational change

G   Mit Bezug auf Veränderungen im Unternehmen, wovon ist es abhängig, in welchem Unternehmensbereich Veränderungen zuerst akzeptiert werden?

E   Regarding organizational change, what does it depend on in which part of the organization changes are typically first accepted?

Preparation: Mutual adoption

G   In wie fern gibt es in der Umsetzungsphase Wechselwirkungen zwischen Änderungen am technologischen Konzept und Änderungen an der Unternehmensstruktur?

E   To what extent do interdependencies exist between technological and organizational change during preparation?

Preparation: Technological change

G   Wie verändert sich bei der Entwicklung einer Lösung die Wahrnehmung, wie gut die Technologie tatsächlich zum Performance Gap, und bestehenden Unternehmen passt?

E   How does the perceived technological compatibility change during preparation, i.e. how well the technological solution fits with the performance gap, organizational structures, and existing infrastructure?

Preparation: Technological change

G   In wie fern kann die neue Technologie den zukünftigen Anwendern bereits in dieser Phase kommuniziert werden?

E   To what extent can the new technology be communicated towards the future operators during this stage?

Preparation: Organizational change

G   Wenn nötig, wie wird die Entwicklung von organisatorischen Veränderungen bereichsübergreifend koordiniert?

E   How is organizational change coordinated across departments, if necessary?

Preparation: Systemic impact

G   Welchen Einfluss haben mögliche Folgewirkungen einzelner Veränderungen auf den weiteren Projektverlauf? In wie fern bestehen Unterschiede in der Vorgehensweise bei Änderungen die Technologie betreffend und Änderungen an der Unternehmensstruktur?

E   What impact do potential follow-up changes of individual changes have on the further project progress? To what extend to differences exist in coping with follow-up changes related to technology and organization respectively?

Installation: Mutual adaptation

G   In wie weit können in der Einführungsphase noch weitere Anpassungen notwendig werden? Sind das typischerweise Anpassungen am Unternehmen oder an der neuen Technologie?

E   To what extent are further changes to technology and organization feasible during installation? Are these typically changes in technology or organization?

Installation: Technological change

G   Wie verändert sich die wahrgenommene Komplexität der technologischen Lösung während der Einführungsphase?

E   How does perceived technological complexity evolve during installation?

Installation: Systemic impact

G   Wie geht man mit unerwarteten systemischen Folgewirkungen während der Einführungsphase um?

E   How do you cope with unexpected systemic impact during installation if necessary?

Interview questions in German (G) and English (E)

Installation: Systemic impact

G Bitte beschreiben Sie, wie grundsätzlich mit einem Change Request umgegangen wird, also wenn die Veränderung von etwas bereits Beschlossenem nötig wird. Gibt es dabei Unterschiede in den verschiedenen Phasen?

E Please describe how you generally handle change requests? What are the differences between handling change requests in different stages of the innovation process, if there are any?

External partners

G In welchen Phasen würden Sie welche externen Partner für wichtig erachten?

E During which stages of the innovation process do you consider external partners to be beneficial?

G Was sind die Herausforderungen bei der Zusammenarbeit mit externen Partnern bei der Prozessentwicklung und wie gehen Sie damit um?

E What are the challenges of working with external partners and how do you cope with these challenges?

Appendix 6: Interview guide II (November and December 2013)

Interview questions in German (G) and English (E)

Introduction

G   Bitte geben Sie mir zunächst einen Überblick, in wie fern Sie bzw. Ihre Abteilung mit dem Thema Prozessentwicklung zu tun haben und welche Rolle verschiedene Arten externe Partner dabei spielen?

E   Please describe your current involvement with process development and implementation and to what extend external partners are relevant for your work?

General issues of open process innovation

G   In wie fern spielt es generell eine Rolle internes Wissen bei der Zusammenarbeit geheim zu halten bzw. zu schützen?

E   To what extent does it matter to protect internal knowledge in collaborations with external partners?

G   Zu welchem Zweck arbeiten Sie in den verschiedenen Phasen jeweils mit externen Partnern zusammen? D.h. also für welche Aktivitäten, um welche Ergebnisse zu erreichen, und um welche Probleme zu adressieren arbeiten Sie mit Partnern zusammen?

E   For what purpose do you work with external partners at different lifecycle stages? Which activities do you seek to carry out, which output do you seek to generate and which problems do you aim to address at different stages of the innovation lifecycle by working with external partners?

G   Bitte beschreiben Sie mir die Rollenverteilung bei der Zusammenarbeit in den verschiedenen Phasen. Mit anderen Worten „Wer macht welche Arbeit in den verschiedenen Phasen"?

E   Please describe the distribution of work responsibilities between you and the external partners at different stages of the innovation lifecycle.

Open process innovation across the innovation lifecycle

G   Unterscheiden Sie im Folgenden bitte zwischen verschiedenen Phasen und alle verschiedenen Arten von Partnern die relevant sind, falls zutreffend.

E   Please, if applicable, distinguish between different lifecycle stages and all types of partners that are relevant in the stages when answering the following questions.

G   Liegen die Beiträge der externen Partner eher im Bereich technologischer Veränderungen, organisatorischer Veränderungen, oder betrifft das eher die gesamtheitliche Betrachtung, also Zusammenführung von Technologie und Organisation?

E   Do external partners contribute more in the area of technological change, organizational change, or to the more holistic task of adapting technology and organization towards each other?

G   Wie gestalten Sie über Geheimhaltungsabkommen hinaus generell den Umgang mit externen Partnern, um Informationen zu erhalten aber gleichzeitig internes Wissen zu schützen?

E   In addition to contractual agreements, how do you interact with external partners in order to acquire external knowledge while simultaneously protecting internal knowledge from unintentional leakage?

G   In wie fern hat die Formalität der Zusammenarbeit einen Einfluss darauf, wie gut Wissen geteilt werden, bzw. auch geschützt werden kann?

E   To what extend does the formality of the relationship affect how well information can be exchanged and protected?

Interview questions in German (G) and English (E)

G   Bitte erklären Sie mir welchen Einfluss die Intensität der Zusammenarbeit generell darauf hat, wie gut Wissen geteilt werden, bzw. wie gut Wissen geschützt werden kann.

      Bitte erklären Sie auch wie Sie Intensität verstehen.

E   Please explain what effect does the intensity of collaboration have on how well information can be shared and protected?

      Please also explain how you understand intensity.

G   Wie stimmen sie sich mit externen Partnern bezüglich der Projektplanung ab?

E   How do you engage in joint project planning with different external partners?

G   Wie gestalten Sie die Kommunikation mit externen Partnern?

      Was ist der hauptsächliche Inhalt der Kommunikation mit verschiedenen externen Partnern, d.h. sind die Inhalte mehr auf die tatsächlichen Veränderungen bezogen oder eher das Projektmanagement betreffend?

E   How do you structure the communication with external partners?

      What is the primary content of the communication with various external partners, i.e. related to actual changes or rather concerning project management?

G   Wie gehen Sie dabei vor einem externen Partner internes Wissen zu vermitteln, das nicht explizit aufgeschrieben oder systematisch dokumentiert ist, sondern eher auf Erfahrungen der Mitarbeiter basiert?

      In wie fern hat das einen Einfluss darauf wie gut Wissen geschützt werden kann?

E   How do you manage to exchange knowledge that is not explicit and codified but more implicit and based on operators' experience?

      To what extend does this affect the degree to which internal knowledge can be protected?

G   Wovon hängt es ab, wie gut Sie das Wissen von einem externen Partner aufnehmen können?

E   What determines how well you can absorb knowledge from an external partner?

Questions specifically related to different lifecycle stages

Ideation

G   Werden Ideen von Partnern vorgetragen, werden interne Ideen mit Partnern besprochen, oder werden Ideen zusammen entwickelt?

E   Are ideas presented by partners, internal ideas discussed with partners, or ideas are developed together?

G   In wie fern können externe Partner dabei helfen Lösungen ganz am Anfang besser zu verstehen?

E   To what extent can external partners help to better understand potential solutions at the very beginning?

Adoption

G   Welche Rolle übernehmen externe Partner bei der Entscheidungsfindung?

E   What role do external partners have during decision making?

G   In wie fern können externe Partner Informationen zu Kosten, Effekten, und anderen Eckdaten eines Projektes liefern?

E   To what extent can external partners provide information on costs, effects, and other key data for a project?

G   In wie fern kann die Koordination zwischen verschiedenen Entscheidungsträgern von externen Partnern unterstützt werden?

E   To what extent can external partners support the coordination between different decision makers?

Interview questions in German (G) and English (E)

G	In wie fern können externe Partner auf eventuelle Folgewirkungen technologischer oder organisatorischer Veränderungen hinweisen?
E	To what extent can external partners point out possible systemic impact of technological or organizational changes?

Preparation

G	Arbeiten Sie gemeinsam an einer Lösung oder getrennt?
E	Do you work together to find a solution or separately?
G	In wie fern werden externe Partner darin involviert technologische Veränderungen vorzunehmen oder organisatorische Veränderungen vorzubereiten?
E	To what extent are external partners involved in technology development or preparing organizational change?
G	In wie fern können externe Partner dabei helfen die Veränderungen den Anwender und den verschiedenen betroffenen Bereichen zu kommunizieren?
E	To what extent can external partners help communicate change to internal stakeholders?

Installation

G	Welche Verantwortung liegt bei der Einführung neuer Prozesse bei den externen Partnern?
E	What is the responsibility of external partners during the introduction of new processes?
G	Welche Rolle spielen externe Partner dabei einen neuen Prozess an die zukünftigen Anwender zu übergeben?
E	What is the role of external partners in handing a new process over to operators?
G	In wie fern können externe Partner dabei helfen Veränderungen mit dem Gesamtunternehmen zu integrieren?
E	To what extent can external partners help with the systemic integration of change?

Appendix 7: Interview tools

THE UNIVERSITY of York

Research framework

Technology

Misalignment

Mutual Adaptation

Technological Change

Systemic Impact

Organizational Change

Fit

Organization

Generic process development life-cycle
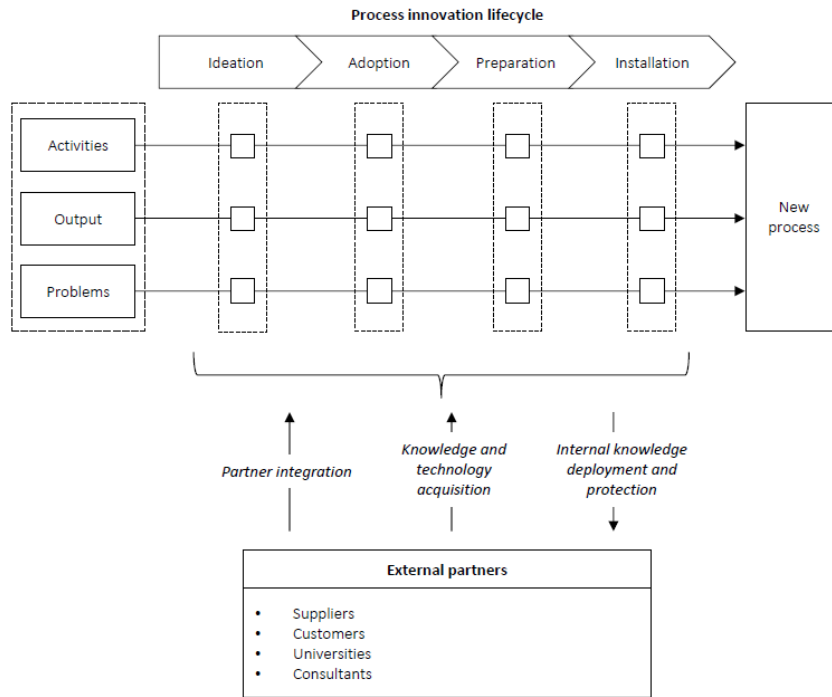
Milewski / Fernandes. StrctrdMdl_PI – UoY-TYMS . DCP1(1./2. 13)

Appendix 8: Participant information sheet

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Participant Information Sheet

Research Project: Managing open process innovation in large manufacturing driven companies (Working title)

Background: Existing management research has thus far greatly contributed to our understanding of inter-firm collaboration with regards to new product development. The management of cooperation with external partners for the development and implementation of new processes has thus far not received adequate attention in the management literature. Because process innovation is significantly different from product innovation further investigations in this area are necessary.

Topic: For my PhD thesis I focus on the management of collaborative process innovation ("open process innovation"). Specifically my research focuses on the identification and analysis of patterns and structures of cooperation between manufacturing driven companies and different external partners for the process innovation. In this context process innovation refers to the systematic development and implementation of new or improved manufacturing or support processes. This includes the development and implementation of new machines or software tools, but also the introduction of new administrative structures. External partners can be universities, suppliers, consultancies, and even competitors, or companies from other industries.

Objective: The result of the study will be a framework for the management of open process innovation. This framework aims to support decision makers to adequately respond to challenges and opportunities involved with the integration of external partners in the development and implementation of new processes. After conclusion of the project an exclusive, practice-oriented white paper on open process innovation will be disseminated to all case study partners. Upon request the results will also be presented

in form of a workshop. The results of the work are further expected to be published in leading academic journals. Of course any confidentiality requirements will be respected (see Section 5: Confidentiality)

Data collection: My work is case-study-based and the required data are collected through semi-structured interviews. Ideally there will be five interviewees from your company that are familiar with the topic of process development. If possible two or three rounds of interviews would be desirable. The interviews are to be held individually with the different participants of the study and will last for around 1-1.5 hours. The interviews will be recorded, unless the interviewee refuses to be recorded. The interviewees are encouraged to review the transcripts of the interview to check for accuracy. Only I and my supervisor Prof. Kiran Fernandes will have access to the collected data. The data collection will begin early 2013. The interviews will deal mainly with the communication, coordination, and cooperation between your company and external partners in the development and implementation of new processes or process components. A short telephone conversation with the individual interview partners would be desirable to resolve any potential issues.

Confidentiality: It would be great if you agreed to have your company name explicitly mentioned as a case study partner for this project. It is, however, also possible to anonymize your company name either partially or completely. Partial anonymity means that name and logo may be used for presentations at the University of York or at research conferences, but are rendered anonymous for any written publications. Individual interviewees will be anonymized without any exception. All data collected will only be accessible by the researcher and his supervisor. Both electronic data and data in paper form are being protected by extensive security measures and destroyed after conclusion of this project. More information on this matter can be requested from the researcher at any point. Furthermore, all case study partners are informed of the other case study companies involved with the project.

Appendix 9: Coding framework

Code	Name and status *(1 initial; 2 emergent)*		Description	No. of sources	No. of refs
Innovation lifecycle					
Ideation					
ILC_01.1	General	1	Content relating to general issues of ideation	36	269
ILC_01.2	Performance Gap Assessment	2	Content relating to problem identification and triggering ideation	27	56
ILC_01.3	Idea Origin	1	Content relating to the sources of ideas for potential solutions	30	99
ILC_01.4	Idea Generation Methods	1	Content relating to how ideas are initially identified and generated	6	8
ILC_01.5	Pre-selection	2	Content relating to the informal elimination of process candidates to create a set of pre-selected ideas	2	3
Adoption					
ILC_02.1	General	1	Content relating to general issues of adoption	41	274
ILC_02.2	TechNovelty	1	Content relating to issues involved in exploring potential novel technologies	14	20
ILC_02.3	Uncertainty	1	Content relating to issues of and coping with uncertainty involved in decision making	21	48
ILC_02.4	ConceptDev	1	Content relating to development of process concepts	35	140
Preparation					
ILC_03.1	General	1	Content relating to general issues in preparation	37	343
ILC_03.2	TechProDevRef	1	Content relating to technology development	23	76
ILC_03.3	InfraDev	1	Content relating to planning organizational changes (structures, processes, operators capabilities)	11	19
ILC_03.4	KnwldgTransf	1	Content relating to knowledge transfer within the organization	17	37
Installation					
ILC_04.1	General	1	Content relating to general issues in installation	37	201
ILC_04.2	Evaluation and Coping	1	Content relating to evaluating the success and coping with issues during implementation	7	16
ILC_04.3	Installation Methods	1	Content relating to physical implementation of new technology and organizational change	27	50
ILC_04.4	Social Uncertainty and Meaning	1	Content relating to issues arising from social uncertainty among organizational stakeholders	10	18

Code	Name and status *(1 initial; 2 emergent)*		Description	No. of sources	No. of refs
Process innovation components					
Mutual adaptation					
PIC_01.1	General	1	Content relating to general activities, outputs, and problems of mutual adaptation	39	330
PIC_01.2	Misalignment	1	Content relating to the role of misalignments between new technology and existing organization	25	47
PIC_01.3	Dynamics and Structure	1	Content relating to managing the coordination of technological and organizational change	11	59
PIC_01.4	Asymmetric adaptation	2	Content relating to adapting either technology or organization more substantially than the other	11	22
Technological change					
PIC_02.1	General	1	Content relating to general activities, outputs, and problems of technological change	41	475
PIC_02.2	Compatibility	1	Content relating to adjusting technology towards existing practices, resources, expectation and requirements	34	150
PIC_02.3	Complexity	1	Content relating to perceived difficulty of understanding and using new technology; includes perceived level of technology novelty or sophistication	24	123
PIC_02.4	Communicability	1	Content relating to issues of specifying, expressing, articulating, or making technology visible to organizational stakeholders	36	177
PIC_02.5	Relative Advantage	1	Content relating to the perception of new technology as superior to the technological status quo	10	25
Organizational change					
PIC_03.1	General	1	Content relating to general activities, outputs, and problems of organizational change	40	347
PIC_03.2	(Dual Core) Coordination	1	Content relating to the coordination of change across different departments, functions, stakeholder groups, and organizational cores	23	110
Systemic impact					
PIC_04.1	General	1	Content relating to general activities, outputs, and problems of systemic impact	34	197
PIC_04.2	Impact Assessment	1	Content relating to assessing the potential systemic impact of change	27	66
PIC_04.3	Change Request Management	1	Content relating to relates to managing requests for change despite completed tasks	23	54

Code	Name and status *(1 initial; 2 emergent)*		Description	No. of sources	No. of refs
Motivation to interact with external partners					
MOT_03.1	General	1	Content relating to general matters of motivation to interact with external partners	19	148
MOT_03.2	Activities	1	Content relating to the activities for which companies seek to interact with external partners	21	138
MOT_03.3	Outputs	1	Content relating to results that companies seek to generate by interacting with external partners	9	22
MOT_03.4	Problems	1	Content relating to the problems that companies seek to address by interacting with external partners	14	48
MOT_03.5	Internal work	2	Content relating to work that is deliberately kept internal and where companies highlight specific shortcomings of external partners	19	112
MOT_03.6	Innovative input	2	Content relating to the motivation of obtaining externally developed technology or methods	13	44
MOT_03.7	Additional Capacity	2	Content relating to the motivation of accessing additional workforce	14	53
MOT_03.8	Partner assessment	2	Content relating to evaluation external actors, before, during, and after collaboration	12	26
MOT_DC1	External Partner Involvement	1	Content relating to work with external partners during first round of data collection	25	122
Openness					
Breadth / Type of partner					
OPN_01.1	General	2	Content relating to external partners in general and cannot be assigned a specific type of external partner	19	201
OPN_01.10	Customers	1	Content relating to business customers and end-users	6	9
OPN_01.11	Others	2	Content relating to specific external partners that cannot be assigned another group but are not important enough for an additional node	7	10
OPN_01.2	Software vendor	1	Content relating to the vendors of software technology	17	193
OPN_01.3	Coach and Trainer	2	Content relating to external partners that provide coaching and training for technologies that they do not sell internally	6	7
OPN_01.3	Consultant	1	Content relating to management consultants	18	194
OPN_01.4	Equipment supplier	1	Content relating to the suppliers of hardware production equipment and components thereof	12	94
OPN_01.5	Universities and Research institutes	1	Content relating to universities and research institutions	14	76
OPN_01.6	Competitors	1	Content relating to companies that operate in the same industry and directly compete with the company	3	6
OPN_01.7	Government	1	Content relating to all government agencies	3	3

Code	Name and status *(1 initial; 2 emergent)*		Description	No. of sources	No. of refs
OPN_01.8	Industrial association	1	Content relating to all industrial consortia, clubs, association, etc. that a company is a member of	6	21
OPN_01.9	Different industry	2	Content relating to partners that operate in a different industry but do not fit with other type of external partner	1	5
Depth					
OPN_02.1	General	1	Content relating to general issues of structuring the interaction with external partners	15	51
OPN_02.2	Information exchange	1	Content relating to the content, frequency and magnitude, and the methods of information exchange	23	297
OPN_02.3	Co-ordination	1	Content relating to administrative planning and formality involved in the interaction	18	81
OPN_02.4	Work performance responsibilities	1	Content relating to the distribution of work responsibilities, i.e. who does what.	18	122
OPN_02.5	Guidelines	2	Content relating to official guidelines for how to interact with external partners	5	6
Knowledge sharing					
OPN_04.1	General	1	Content relating to general issues and relevance of knowledge sharing	20	115
OPN_04.10	Access to internal systems	2	Content relating to granting external partners access to internal systems	2	7
OPN_04.2	Current work practices	2	Content relating to educating external partners about how work is currently performed	10	13
OPN_04.3	Tacit v Explicit knowledge	1	Content relating to issues of conveying tacit knowledge and conveying explicit knowledge	14	35
OPN_04.4	Need-to-know	2	Content relating to sharing as much knowledge as necessary for the external partner to make a contribution but not more	13	34
OPN_04.5	Solution driven approach	2	Content relating to relates to considering knowledge sharing as necessary to achieve more important goals	13	29
OPN_04.6	Experience	2	Content relating to experiences task force members have with regards what can be shared with external partners	4	5
OPN_04.7	Access to different functions	2	Content relating to relates to whom the external partner is in contact with inside the company	3	4
OPN_04.9	Knowledge spillovers	2	Content relating to knowledge spillovers (inside-out) that occur during interaction with external partners	7	17

Code	Name and status *(1 initial; 2 emergent)*		Description	No. of sources	No. of refs
Knowledge sharing					
OPN_05.1	General	1	Content relating to general issues and relevance of knowledge protection	17	58
OPN_05.10	Awareness	2	Content relating to the general awareness that knowledge protection is important	14	31
OPN_05.11	Appropriability	2	Content relating to specific emphasis on the importance of knowledge protection for the exploitation process innovation	6	14
OPN_05.12	Firm size and bargaining	2	Content relating to the effects of the company size and the bargaining power on the opportunities for knowledge protection	4	5
OPN_05.13	Certification	2	Content relating to legal requirements for knowledge protection	2	2
OPN_05.2	Product data	2	Content relating to the protection of product related data	10	17
OPN_05.3	Process know-how	2	Content relating to the protection of knowledge about internal processes	14	54
OPN_05.4	Difficulties with knowledge protection	2	Content relating to issues that make it difficult to protect internal knowledge	9	18
OPN_05.5	Specific knowledge and integration as protection	2	Content relating to knowledge that is specific to the company and coherency as a mechanisms for knowledge protection	4	18
OPN_05.6	Partner selection as protection mechanism	2	Content relating to selecting partners with specific characteristics as a mechanism for knowledge protection	5	15
OPN_05.7	Legal Agreements	2	Content relating to any form of legal mechanisms to protect internal knowledge	21	77
OPN_05.8	Trust	2	Content relating to trust between companies and its effect on knowledge protection	16	32
OPN_05.9	Protection strategies	1	Content relating to specifically formulated approaches to protect internal knowledge	18	87
(Further) Emerging topics					
ETC_01.01	Relevance of Change	2	Content relating to the importance of changing processes	6	12
ETC_01.02	Expectations	2	Content relating to expectations towards process innovation and managing expectations	23	58
ETC_01.03	Top Management Support	2	Content relating to change initiated or supported by top-management, including top-down enforcement of projects and ideas	15	38
ETC_01.04	Workaround	2	Content relating to coping with unexpected consequences that cannot be covered in current project (cf. ETC_01.23;43)	8	14
ETC_01.06	Follow Up Projects	2	Content relating to reasons why changes have to be addressed in new projects rather than current ones	10	18

Code	Name and status *(1 initial; 2 emergent)*		Description	No. of sources	No. of refs
ETC_01.07	User Acceptance	2	Content relating to how users, operators, or employees accept a change or accept an external partner	34	112
ETC_01.08	Sources for innovation	2	Content relating to the origins of innovation and how they may be discovered	4	4
ETC_01.09	Org. Processes	2	Content relating to the management of changing existing processes (later integrated with ETC_02.03).	18	74
ETC_01.10	Future Developments	2	Content relating to how useful new processes are expected to be given future developments of the firm, market, etc.	4	6
ETC_01.11	Extendibility	2	Content relating to opportunities for modifying technologies in future (later integrated with ETC_01.11;29)	5	6
ETC_01.12	Prototyping	2	Content relating to early concepts, pilot projects, tests, and prototyping of processes or technology	10	21
ETC_01.13	Business Improvement	2	Content relating to continuous improvement and change occurring after initial installation (see also ETC_01.06)	13	21
ETC_01.14	Usability	2	Content relating to how well a new process can be used or applied in a practical sense.	7	9
ETC_01.15	Emergent Solutions	2	Content relating to solutions that emerged rather than having been systematically developed (Later integrated with ILC_01.03)	4	7
ETC_01.16	Diffusion	2	Content relating to how a new process or technology were rolled out within a firm or corporation (later integrated with ETC_01.25)	6	8
ETC_01.17	Project Champion	2	Content relating to the role of a project champion in process development and implementation	11	23
ETC_01.18	Product Development	2	Content relating to Product innovation or product development related issues	11	19
ETC_01.19	Time Pressure	2	Content relating to the role of deadlines and time pressure in process development projects	12	22
ETC_01.20	Continuous Assessment	2	Content relating to the continuous assessment of work, expectations, progress, etc. during a process innovation project	21	42
ETC_01.21	Good Enough Solutions	2	Content relating to partial solutions or solutions that were implemented despite not matching the expectation to 100%	10	16
ETC_01.22	User involvement	2	Content relating to the involvement of operators in process development and implementation and bottom-up innovation	22	65
ETC_01.23	Resource constraints	2	Content relating to the effect of limited resources or capacity on the development and introduction of new processes	8	16
ETC_01.24	Drivers for Change	2	Content relating to how and why change is initiated	10	15

Code	Name and status *(1 initial; 2 emergent)*		Description	No. of sources	No. of refs
ETC_01.25	Successive Rollout	2	Content relating to the diffusion of new processes and technologies within the company (later integrated with ETC_01.16)	6	15
ETC_01.26	Corporate Level Diversity	2	Content relating to issues evolving around different functions or departments within a corporation working together (later integrated with PIC_03)	14	31
ETC_01.27	Standardization	2	Content relating to the role of standardized solutions (later integrated with ETC 02.03)	18	37
ETC_01.28	Future Direction	2	Content relating to future developments (later integrated with ETC_01.10)	2	3
ETC_01.29	Ongoing Development	2	Content relating to change that occurs on an ongoing basis and not just within a project (later integrated with ETC_01.11)	8	10
ETC_01.30	Human Factor	2	Content relating to management issues related to social issues in process development and implementation	17	37
ETC_01.31	Utility & Benefits	2	Content relating to the perceived utility and benefits of change and the actions they provoke (later integrated with PIC_02.5)	16	41
ETC_01.32	Manufacturing Strategy	2	Content relating to the relevance of manufacturing strategies	3	3
ETC_01.33	Information Distribution	2	Content relating to distributing information internally (later integrated with ETC_01.16)	2	3
ETC_01.34	Coping Mechanisms	2	Content relating to mechanisms operators use to cope with unwelcomed change (later integrated with ETC_01.07)	2	3
ETC_01.35	Proven Technology	2	Content relating to learning about experiences others have made with a particular technology (later integrated with PIC_02.1)	3	3
ETC_01.36	Unstructured Preselection	2	Content relating to informal preselection of process candidates (later integrated with ILC_01.05)	5	5
ETC_01.37	Global availability	2	Content relating to the implementation of new processes in facilities around the globe (later integrated with ETC_01.25;16)	5	6
ETC_01.38	Path Dependency	2	Content relating to effect of old structures, processes, etc. on process innovation	7	15
ETC_01.39	Integration	2	Content relating to the systemic integration of new processes (later integrated with PIC_04.1)	2	2
ETC_01.40	Identifying Criteria	2	Content relating to the how companies decide how to make decisions (later integrated with concept development in ILC_02.4)	3	3
ETC_01.40	Project management	2	Content relating to project management techniques	9	19
ETC_01.41	Business Model	2	Content relating to particular issues relating to the business model of a specific firm	4	6

Code	Name and status (1 initial; 2 emergent)		Description	No. of sources	No. of refs
ETC_01.42	Environmental Changes	2	Content relating to changes in a firms environment which may induce change (later integrated with ILC_01.03)	3	3
ETC_01.43	Budget effect on collaboration	2	Content relating to the effect of resources on collaboration with external partners (later integrated with ETC_01.23)	7	16
ETC_01.44	International Business	2	Content relating to process innovation and/or collaboration in context of doing internal business	4	6
ETC_01.45	Partner establishment	2	Content relating to the effect of the partner's market establishment on the collaboration with this partner	4	9
ETC_01.46	Partner development	2	Content relating to the development of a partner for long-term collaboration	8	14
ETC_01.47	Change of project members	2	Content relating to the effect of project team composition across the innovation lifecycle	5	5
ETC_01.48	Industrial background partner	2	Content relating to the partner's main industry and the characteristics of the industry	1	1
ETC_01.49	Project specification	2	Content relating to defining a project and how it is described what the project is supposed to comprise	10	36
ETC_01.50	AdHoc Management	2	Content relating to managing issues spontaneously (later integrated with ETC_01.40)	2	3
ETC_01.51	Identification	2	Content relating to the task forces identification with a particular project or the firm (later integrated with ETC_01.30)	6	10
ETC_01.52	Boundary spanning processes	2	Content relating to processes that are cross-organizational (later integrated with ETC_02.04)	3	4
ETC_01.53	Top-down	2	Content relating to enforcing change top-down (later integrated with ETC_01.03)	1	1
ETC_01.54	Systems Engineering	2	Content relating to Systems Engineering	2	7
ETC_01.55	Legal commitment	2	Content relating to the legal specification of committing to a specific project (later integrated with ETC_01.49)	1	3
ETC_02.01	ILC General	2	Content relating to every statement that related to process innovation but did not fit into specific lifecycle stages	38	552
ETC_02.02	ILC Routinization	2	Content relating to every process innovation related activity that referred specifically to the operational stages and the routinization after installation	19	35
ETC_02.03	PIC General	2	Content relating to process innovation in general but cannot be assigned to a specific process innovation component	25	220
ETC_02.04	Type of process	2	Content relating to differences between different types of processes	14	72

Appendix 10: Relationships between different levels of abstraction

Structure of findings and relationships between different levels of abstraction

Sub-categories		Themes	C1: External contributions to technological change	C2: Methodological guidance by management consultants	C3: The nature of further external contributions	C4: Capability deployment for open process innovation
PIC-1.1	Mutual adaptation for process description and evaluation	**Theme 1.1:** Motivation for interaction and type of process affect openness of interaction with external technology experts during ideation	✔		✔	
PIC-1.2	Technological change as identification and pre-selection of new technologies					
MOT-1.1	Gathering information on available technologies to fertilize ideas					
OPN-1.1	Weak interaction with technology experts					
OPN-1.2	More specific interaction with technology experts					
PIC-2.1	Mutual adaptation as an important decision criterion	**Theme 2.1:** Motivation for interaction and type of process affect openness of interaction with external technology experts at the adoption stage	✔		✔	
PIC-2.2	Technological concept development to reduce uncertainty					
MOT-2.1	Access to technological information as motivation for interaction with technology suppliers					
OPN-2.1	Interaction with technology suppliers during concept development					
PIC-3.1	Managing the coordination of change during preparation	**Theme 3.1:** Differences in motivation and openness towards technology suppliers exist between enabling and core processes during preparation	✔		✔	
PIC-3.2	Understanding and developing technology					
MOT-3.1	External support for technology development					
OPN-3.1	Structure of interaction for technology development					
OPN-3.2	Knowledge sharing and protection for technological change contribution					

Sub-categories		Themes	C1: External contributions to technological change	C2: Methodological guidance by management consultants	C3: The nature of further external contributions	C4: Capability deployment for open process innovation
PIC-4.1	Further adaptation	**Theme 4.1:** External contributions are relevant for capacity and temporarily necessary capabilities during installation	✔		✔	
PIC-4.2	Technology installation and handover to operators					
MOT-4.1	Additional capacities for technology implementation					
OPN-4.1	Structure of work responsibility distribution					
OPN-4.2	Knowledge sharing and protection					
OPN-4.1	Structure of work responsibility distribution	**Theme 4.2:** Converging results for relevance of knowledge protection and work responsibility distribution for core and enabling processes during installation	✔		✔	
OPN-4.2	Knowledge sharing and protection					
PIC-3.3	Coordinating emerging organizational changes	**Theme 3.2:** External contributions towards organizational change and systemic impact remain limited during preparation			✔	
PIC-3.4	Systemic impact assessment					
MOT-3.2	Limited contributions to organizational change					
PIC-1.1	Mutual adaptation for process description and evaluation	**Theme 1.2:** Project scope affects the relevance of management consultants as external partners during ideation		✔		
PIC-1.2	Technological change as identification and pre-selection of new technologies					
PIC-1.3	The existing organization as a reference framework					
PIC-1.4	Difficulties of systemic impact assessment					
MOT-1.2	Obtain methodological guidance					
OPN-1.3	Frequent and in-depth interaction with consultants					

Sub-categories		Themes	C1: External contributions to technological change	C2: Methodological guidance by management consultants	C3: The nature of further external contributions	C4: Capability deployment for open process innovation
PIC-2.1	Mutual adaptation as an important decision criterion					
PIC-2.2	Technological concept development to reduce uncertainty					
PIC-2.3	Organizational change considerations during decision making	**Theme 2.2:** Project scope affects the relevance of management consultants as external partners at the adoption stage		✔		
PIC-2.4	Systemic impact considerations during decision making					
MOT-2.2	Methodological support during concept development and decision making					
OPN-2.2	Structure of interaction with management consultants					
PIC-1.1	Mutual adaptation for process description and evaluation					
PIC-1.2	Technological change as identification and pre-selection of new technologies					
PIC-1.3	Existing organization as a reference framework	**Theme 1.3:** Knowledge absorption is nascent, tentative, and confined to the task force during ideation			✔	✔
PIC-1.4	Difficulties of systemic impact assessment					
MOT-1.1	Gather information on available technologies to fertilize ideas					
OPN-1.1	Weak interaction with technology experts					
OPN-1.2	More specific interaction with technology experts					

Sub-categories		Themes	C1: External contributions to technological change	C2: Methodological guidance by management consultants	C3: The nature of further external contributions	C4: Capability deployment for open process innovation
PIC-2.1	Mutual adaptation as an important decision criterion	**Theme 2.3:** Further knowledge absorption occurs with particular focus on adjusting expectations and requirements at the adoption stage			✔	✔
PIC-2.2	Technological concept development to reduce uncertainty					
PIC-2.3	Organizational change considerations during decision making					
PIC-2.4	Systemic impact considerations during decision making					
MOT-2.1	Access to technological information as motivation for interaction with technology suppliers.					
OPN-2.1	Interaction with technology suppliers during concept development					
PIC-3.1	Managing the coordination of change during preparation.	**Theme 3.3:** Practical adaptation occurs in addition to further assimilation and transformation during preparation			✔	✔
PIC-3.2	Understanding and developing technology					
PIC-3.3	Coordinating (emerging) organizational changes					
PIC-3.4	Systemic impact assessment					
MOT-3.1	Contributions to technological change					
OPN-3.1	Structure of interaction for technology development					
OPN-3.2	Knowledge sharing and protection for technological change contributions					

Sub-categories		Themes	C1: External contributions to technological change	C2: Methodological guidance by management consultants	C3: The nature of further external contributions	C4: Capability deployment for open process innovation
PIC-4.1	Further adaptation	**Theme 4.3:** Exploitation, integration, and further transformation during installation				✔
PIC-4.2	Technology installation and handover to operators					
PIC-4.3	Organizational change and addressing social uncertainty					
PIC-4.4	Systemic integration management					
MOT-4.1	Additional capacities for technology implementation					
OPN-4.1	Structure of work responsibility distribution					
PIC-1.3	The existing organization as a reference framework	**Additional Theme X:** Not directly supported by external partners during innovation lifecycle			✔	
PIC-2.3	Organizational change considerations during decision making					
PIC-3.3	Coordinating (emerging) organizational changes					
PIC-4.3	Organizational change and addressing social uncertainty					

Glossary: Definition of key terminology as used in thesis

Term	Definition and operationalization
Activities (in context of characterizing innovation lifecycle stages)	Refer to the performance of a specific function or task by an organizational unit in order to create outputs and resolve problems at any given stage of the innovation lifecycle
Actual data	Data that describes real values of real operations
Applied capability contribution	Capability contributions are applied if external partners use their capabilities to provide tangible support for technological change which enables companies to develop experience-based understanding of new technology
Appropriation	Capturing the returns on investment in innovation
Capability	Refers to bundles or sets of differentiated skills, complementary assets, and routines that provide the basis for a firm's competitive capacities and sustainable advantage in a particular business
Capability contribution	Companies seek capability contributions when they seek interaction with external partners to absorb knowledge and develop capabilities that are not yet available but considered necessary to possess internally
Capacity	Refers to groups of capabilities that can be used for a common purpose but may be significantly different from each other
Capacity contribution	Companies seek capacity contributions when they are motivated to interact with external partners to access additional workforce or resources to carry out specific tasks, although the necessary capabilities to perform these tasks are available or when they are not needed internally
Category	Refers to the theoretical "bins" into which the data was organized and that are central to the study of open process innovation from a lifecycle perspective.
Conceptual capability contribution	Capability contributions are conceptual if external technology experts use their capabilities to help companies generate a theoretical understanding of new technology, based on the provision of information but not practical experience
Construct	Refers to ideas or theories that express general, abstract principles or meanings but are not directly observable and consist of multiple underlying elements. In context of the present thesis constructs are theoretical principles of open process innovation that emerge from the themes of open process in different lifecycle stages.
Data	Any symbols that represent properties of any objects, processes, or events; In context of this study, data refer to the concrete evidence on open process innovation collected from practitioners
Direct contributions	Refer to information or practice that enables or supports a specific activity, which the information or practice is specifically addressing
Dummy data	Refers to made-up data that does not describe real values
Framework category	Refers to main parts of the initial conceptual framework (Process innovation components, motivation for interaction, and openness)
Indirect contributions	Refer to information or practice that enables a specific task although the information did not originally relate to that specific task. The specific task, however, relates to an issue that refers to the same project as the issue the information originally referred to. Indirect contributions do not threaten the providers' knowledge base

Term	Definition and operationalization
Information	Refers to data that has been processed into a meaningful and useful form. Answers questions of who what where and when; Can be exchanged across organizational boundaries; information is confidential (or critical) when it relates to knowledge about core processes, products, or operations of a company
Information availability	Describes the extent to which relevant information is readily accessible from external sources without (additional) substantial up-front investments, as perceived by the interviewees
Internal acceptance	Refers to the willingness of internal stakeholders to work with and put into practice the input from change agents
Knowledge	Refers to the application of data and information; answers questions of how; May equally result from information exchange
Methodological support	Refers to range of contributions that neither relate to technological or organizational change directly but to a range of contributions that provide companies with tools and support for the identification and evaluation processes
Motivation (MOT)	Describes the purpose for which companies interact with external partners
Mutual adaptation	Refers to the deliberate, reciprocal coordination of technological and organizational change to overcome misalignments between a new technology and an existing organization; comprises technological and organizational change
Open process innovation	Refers to collaboration between a company and its external partners for the development and implementation of new internal processes
Openness (OPN)	Describes the basic idea of boundary spanning innovation; only considering inbound and coupled innovation processes (investigated in terms of search breadth and depth)
Organizational change	Describes the coordination, planning, and implementation of changes to work organization (investigated with specific focus on the coordination of change among stakeholders)
Organizational insight	Generally refers to tacit and explicit knowledge about the company; may include for example internal structures, processes, culture, value, history, etc.
Output (in context of characterizing innovation lifecycle stages)	Refers to the result of the actions of internal and external organizational actors at the different stages of the innovation lifecycle; need to be created at each lifecycle stage to provide input for the next stage
Problems (in context of characterizing innovation lifecycle stages)	Describe difficulties, challenges, and risks involved in performing certain activities or achieving certain outputs at any given stage of the innovation lifecycle; need to be resolved to achieve the desired outputs at any given lifecycle stage
Process innovation	Refers to new or significantly improved organizational processes enabled by the use of new technology, and may include new machines, production equipment, information technology, or managerial practices and work organization
Process innovation components (PIC)	Refers to topics that are characteristic of technological process development and implementation (mutual adaptation, technological change, organizational change, systemic impact)

Term	Definition and operationalization
Project scope	Second dimension of replication logic for the case selection for this study; Describes the extent of the area or subject matter that something deals with or to which it is relevant
	Broad scope projects include technological and organizational change. Involve a focus on one or more technologies. Involve organizational change across multiple organizational departments and functions and possibly multiple sites at the same time.
	Narrow scope projects include mainly technological change and require only minor organizational change coordination Involve only one technology. Are limited to a specific department or setting. Involve organizational change which are limited to a specific department or setting and do not include simultaneous roll-out in various heterogeneous functions, departments, or locations.
Relevance of knowledge protection	Describes the extent to which access to information that relates to critical or confidential knowledge becomes necessary in order to perform specific activities and create specific outputs
Resources	Refer to all assets available to a company. This comprises physical capital resources, such as hardware and software technology, research and production facilities, or raw materials; human capital resources such as operators, training, experience, networks and relationships, or managerial expertise; and organizational capital resources like reporting structures, and planning or coordination systems
Routines	Refer to patterns of collective activities, behaviors, and interactions within company. They are effortful accomplishments that can be subject to change and variation; they include recurrent patterns of action, as well as rules, standard operating procedures, and so on; they are generally defined as mechanisms by which companies enact and develop capabilities
Search breadth	Describes the qualitative composition rather than merely the aggregate number of a company's external partner diversity. In addition, the study investigates the rationale behind the composition of search breadth, i.e. the potential link between search breadth and the motivation for interaction
	Broad: interacted with numerous partners and different types of partners and partners from various backgrounds
	Narrow: there was only one external partner
Search depth	Captures the extent to which companies draw intensively from search channels or sources of innovative ideas. The structure of interaction between a company and its external partners. The sub-dimensions that describe interaction include the exchange of information with external partners (communication), joint planning activities (coordination), and work performance distribution (cooperation)
	Strong: Interaction involves substantial mutual exchange of specific, potentially critical, process related information between the company and an external actor for technical problem solving. There is formality and close collaboration: tasks and objectives are defined but there is flexibility for conjoint problem solving
	Medium: Interaction involves some mutual exchange of specific, potentially critical, process related information between the company and an external actor for technical problem solving. There is formality but no close collaboration: tasks and objectives are defined, there is some flexibility for problem solving but little to no conjoint problem solving

Term	Definition and operationalization
	Weak (1): Interaction involves little or no mutual exchange of specific, potentially critical, process related information between the company and an external actor for technical problem solving. There is formality but no close collaboration: tasks and objectives are clearly defined, structured, and rigid
	Weak (2): Interaction involves no specific information, no formality, and no collaboration
Systemic impact	Describes the repercussions of process related change beyond the focal point of process introduction (investigated with regard to the activities, outputs, and problems relating to systemic impact assessment and systemic integration of new processes)
Technological change	Managing technology change comprises all activities, outputs, and problems related to the identification, development, modification, and implementation of new technology. This does not refer to idiosyncratic technology change in specific projects. Instead, it describes activities, outputs, and challenges related to a technology's relative advantage, complexity, compatibility, and observability/communicability
	Relative advantage: The degree to which a technology is perceived as superior to the technological status quo as described along relevant categories
	Compatibility: The extent technology is perceived as consistent with existing practices, resources, and needs of the organization. This involves concern for complementarity and conflict with other components of an affected process
	Complexity: The extent technology is perceived as difficult to understand and use, including the degree to which it is perceived to be novel or sophisticated
	Communicability/Observability: The extent to which the technology can be specified, expressed, articulated, or made visible to other members within the organization
Technology	The application of scientific knowledge for practical (industrial) purposes
Technology transfer	Refers to movement of physical equipment, transfer of the necessary skills to operate the equipment, and an understanding of embedded cultural skills
Theme	Describe recurring subjects or topics within a specific context; may span several categories at a given lifecycle stage.
Type of process	First dimension of replication logic for the case selection for this study. Can refer to enabling or core processes
	Enabling process: Enabling processes are important organizational processes but they are not directly related to the primary activities of the company but instead facilitate them
	Core processes: Core processes describe such activities that are directly related to the creation of the primary value for customers
Understanding	Appreciation knowledge (and information), answering why questions

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